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Post-Construction Support and Sustainability in Community-Managed Rural Water Supply

Case Studies in Peru, Bolivia, and Ghana

Alexander Bakalian and Wendy Wakeman, editors

World Bank – Netherlands Water Partnership

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Cover photo (right side): Heather Lukacs.

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ABBREVIATIONS AND ACRONYMS

BID/IDB	Inter-American Development Bank
CINARA	*Instituto de Investigación y Desarrollo en Agua Potable Saneamiento Basico y Conservacion del Recurso Hídrico* (Colombia)
COSUDE	Swiss Development Agency
CTAR	Regional Transitional Government of Cuzco
CWSA	Community Water and Sanitation Agency (Ghana)
DWST	District water and sanitation team (Ghana)
EHP	Environmental Health Project (USA)
ENACAL	*Empresa Nicaragüense de Acueductos y Alcantarillados* (Nicaragua)
ENACAL-GAR	*Gerencia de Acueductos Rurales* (Nicaragua)
FONCODES	Social Investment Fund of Central Government of Peru
HH	Household
IISS	International Institution for Sustainable Development
IRC	International Water and Sanitation Center (Netherlands)
JASS	*Junta administradora servicios saneamientos* (Peru)
MINSA	*Ministerio de Salud* (Peru)
NE	*Nucleo ejecutor* (Peru)
NGO	Non-governmental organization
O&M	Operation and maintenance
OED	Operations Evaluation Department (World Bank)
PCS	Post-construction support
PROSABAR	Project of the National Directorate of Water and Sanitation (Bolivia)
RWS	Rural water supply
SANAA	*Servicio Autónomo Nacional de Acueductos y Alcantarillados* (Honduras)
SANBASUR	*Saneamiento Basico en El Sierra Sur* (Peru)
SENASA	*Servicio Nacional de Saneamiento Ambiental* (Paraguay)
UK	United Kingdom
UNICEF	United Nations Children Fund
UNOM	*Unidad de Operación y Mantenimiento* (Nicaragua)
USAID	United States Agency for International Development
VWC	Village water committee
WSP	Water Supply and Sanitation Program
WSS	Water supply and sanitation

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The research would not have been possible without our collaborators in Peru, Bolivia, and Ghana.

EXECUTIVE SUMMARY

This volume reports the main findings from a multi-country research project that was designed to develop a better understanding of how rural water supply systems are performing in developing countries. We began the research in 2004 to investigate how the provision of support to communities after the construction of a rural water supply project affected project performance in the medium term. We collected information from households, village water committees, focus groups of village residents, system operators, and key informants in 400 rural communities in Bolivia, Ghana, and Peru; in total, we discussed community water supply issues with approximately 10,000 individuals in these communities.

To our surprise, we found the great majority of the village water systems were performing well. Our findings on the factors influencing their sustainability will, we hope, be of use to policy makers, investors, and managers in rural water supply.

Evolving approaches to rural water supply and post-construction support

Since the mid-1990s a number of donors, working with national and regional water resources ministries in developing countries, have designed and implemented community-managed rural water supply (RWS) programs that incorporate one or more components of the demand-driven model: (1) involving households in the choice of technology and of institutional and governance arrangements; (2) giving women a larger role in decision making than had been the norm; and (3) requiring households to pay all of the operation and maintenance costs of providing water services and at least some of the capital costs. The new model would, it was hoped, improve on the earlier dismal record of rural water supply projects, many of which had quickly fallen into disrepair.

Few of the community-managed RWS programs planned for systematic provision of post-construction support. But, increasingly, observers have argued that it is unrealistic to leave rural communities to their own devices after a water project is completed, and that for rural water supply systems to be successful, communities need some post-construction support (PCS), such as follow-up training, and technical assistance visits by engineers.

Two broad approaches to providing PCS have emerged. The first is to ensure that spare parts and technical services are available, but to leave the responsibility largely to communities themselves to seek out such services and to pay for them when needed. The second is a more supply-driven approach: to provide communities with unsolicited support for repairs, technical assistance, training, and trouble-shooting.

Focus of the research

We wanted to investigate the effect of supply-driven post-construction support on system sustainability when added to a well-designed community-managed rural water supply program. In all three countries, we selected villages that had received improved water supply projects three to twelve years earlier as part of such programs. About half the villages in our sample were “treatment” villages—that is, they had received supply-driven post-construction support arranged by the rural water supply program—and half were “controls”—that is, they had not received such support. In all three countries, we used secondary data to help us choose districts or regions where the characteristics of villages and households in the treatment and control villages were likely to be similar.

In all three countries, we found some unexpected challenges. Our research design required that the water systems in some villages be “successes” and in others “failures,” in order to have variation in our dependent variable. In fact, we found far fewer project failures in either treatment or control villages than expected: the great majority of the water systems were being sustained.

Another threat to our research design was the complexity of PCS provision in the study settings. Though we had tried to select PCS programs that were supply-driven, we found that such programs often do not work that way in practice. The MOM program in Ghana turned out to be the only true supply-driven PCS program in our three study sites: villages in this program were receiving quarterly visits from environmental health assistants to monitor the technical, management, and financial status of their rural water supply systems. More commonly, we found that both treatment and control communities in the three countries were seeking out PCS when their water systems broke down or when there was a management problem or conflict. Thus in practice much PCS was demand-driven. Communities sought help from wherever they could get it—including nongovernmental organizations, nearby municipalities, or even large commercial enterprises.

Overview of findings

The demand-driven, community-management model seems to be working, at least in the medium term. Not only were the rural water systems producing water (i.e., not broken down), but almost all the households in these communities were obtaining at least some of their water from the systems. And in all three countries the vast majority of village water committees (VWCs) were functioning as planned.

Communities had been involved in pre-construction planning and helped with capital costs. Community members in all three countries felt that they had been involved in the pre-construction planning of their water systems. In all three countries, more than 90 percent of the focus groups that we held with village leaders and/or women reported that the community had been involved in tariff design. In about two thirds of the villages in Bolivia and Peru (vs. 42 percent in Ghana), people felt they had been involved in the choice of technology. In just under half the villages in all three countries, people felt they had contributed to decisions on the location of the proposed infrastructure. In all three countries, communities contributed 5–10 percent of the capital costs of the project, though in many cases labor and/or land contributions were allowed to substitute for cash.

Community water supply projects were still working. All the piped systems studied in Peru, and all but one of those studied in Bolivia, were functioning at the time of our field visit. Among the households in our sample in Peru and Bolivia, 93 percent or more had operational taps at the time of our field visit. In 55 percent of the communities in Bolivia and 76 percent in Peru, all the household taps were working. In 90 percent of the villages in Ghana, all project boreholes were still working. In Bolivia, all the households who were interviewed reported using water from the improved water system; in Ghana 97 percent; and in Peru 95 percent. In Ghana, households were collecting 34 liters per day from boreholes in Volta and 24 liters per day in Brong Ahafo.

Villages used post-construction support from wherever they could get it. The systems in all three countries did occasionally break down, but in the majority of cases the VWCs had been able to arrange for repairs. Most of the sample villages in all three countries reported they had had one or more breakdowns in the last six months, but in Bolivia breakdowns were typically fixed in one to two days, in Peru in five days, and in Ghana in 18 days. Even communities that were not collecting enough revenues to pay for operation and maintenance costs were finding the resources needed to fix their systems when they broke down. Especially in Ghana, many of these resources came from outside the community. Communities were using a wide variety of government- and NGO-provided PCS services to keep their systems working. Some of the services were provided at their own request ("solicited PCS") and others arrived on the initiative of government or NGO or church organizations ("supply-driven PCS").

Consumer satisfaction was high. Given that in general the water systems were working and that communities were able to make repairs, levels of household satisfaction were very high in most villages in all three countries. On average, in Bolivia 83 percent of households in each village reported being "satisfied" or "very satisfied" with their system's operation and maintenance regime, and 78 percent were "satisfied" or "very satisfied" with the performance of their VWC. In Peru, 61 percent of the households reported that they were satisfied overall with their improved water system. In Ghana, 88 percent of the households reported they were satisfied with the repair and maintenance services of the water system, and more than 80 percent of the women's focus groups said they were satisfied with the system.

There are also some troubling findings:

Households were still using unprotected water sources. Although almost all households reported using the new water systems, for some this was not their only water source. In Ghana, 38 percent of households were still using water from unprotected sources for drinking and/or cooking. The percentages were lower in Peru (21 percent) and Bolivia (23 percent), but still worrisome. We speculate that until households obtain their drinking and cooking water exclusively from improved sources, the health benefits of the investments in improved sources will not be fully realized.

The finances of many village water committees were in poor shape. Households in the sample villages were paying very little for the improved water services. As designed, these rural water supply programs did not require communities to finance the capital costs of construction or to provide for capital replacement or expansion; the cost-recovery objective was simply to collect enough revenues from users on an ongoing basis to pay operation and maintenance costs. But a substantial minority of villages in our study were not achieving even this modest objective.

Generally, more analysis is required to assess the impact of PCS on sustainability and satisfaction. Our cross-sectional research design and the varied character of PCS in all three countries made it very difficult to draw definitive conclusions about the contribution of different forms of PCS to system sustainability or to household satisfaction. Our results merit further investigation in other field sites.

In none of the three countries did we find a statistically significant association between a village receiving a technical PCS visit (to help with repairs or maintenance) and having a working water system. But post-construction technical training of system operators or caretakers was positively associated with system performance in both Ghana and Bolivia. In Bolivia, the share of households who were satisfied was, on average, 15 percentage points higher if the village had received a PCS visit that provided financial or managerial (though not technical) assistance.

All in all, we found no evidence that supplying communities with free repairs or free technical assistance, or that implementing an intensive supply-driven post-construction support program like MOM in parts of Ghana, improved either technical sustainability or household satisfaction.

Implications for sustaining and expanding RWS systems

These findings seem to support the concept of the demand-driven community management model—that communities can and should take full responsibility for their systems. The unsolicited PCS activities that appear most promising are those that help communities to renew and further develop their capacities: post-construction training for system operators and non-technical support visits to help village water committees with administrative functions or water use disputes.

Important puzzles remain, however, for policy makers, investors, and managers in rural water supply. One is that even those communities whose cost-recovery systems seem to be meeting program objectives—by paying 5–10 percent of capital costs and collecting tariffs to cover operation, maintenance, and repairs—are not moving toward a financially sustainable future in which they can either (1) replace infrastructure when it reaches the end of its economic life, or (2) expand system capacity to accommodate population and economic growth. The donor-funded rural water supply programs studied have been structured as one-time investment programs, designed to meet only immediate needs. This means that the moral obligation assumed by higher-level government and donors is not over. The current financing system ensures that these communities will keep returning for capital subsidies, just as some are doing now for repairs.

In a significant number of villages, the water committees are not collecting tariffs at all, or are collecting too little revenue from households to cover the financial costs of major repairs—much less the costs of system expansion or capital replacement. Our findings suggest three principal reasons why. First, generating substantial cash balances creates difficult problems for the committees. These rural communities, many of them quite remote, lack access to a convenient, secure banking system for managing cash. Moreover, many households have little cash to spare, and cash flow is irregular and highly seasonal. Households are also often distrustful of the accounting and security of cash balances, and water committee members may distrust each other or not want the responsibility of securing cash. Second, when the committees do accumulate cash balances, villages often want to spend these monies on other development projects; in such a situation, it makes sense to try to raise funds only when the need arises. Third, water committees may well be right to believe that future capital and repair subsidies will be forthcoming when needed, whether from donors, NGOs, or higher levels of government. In the projects studied, not only was the bulk of the capital provided at no cost to the communities at the time of construction, but a significant number of village water committees had obtained donations, free spare parts, and free repairs from a wide variety of NGOs, church organizations, private individuals and companies, and even local governments.

The water supply systems in the communities in our sample are not financially sustainable without new infusions of capital relatively soon—both to replace existing infrastructure and to provide for growth. It may be that the sector's current capital financing model—and the post-construction activities of NGOs and other actors—creates a moral hazard that will undermine the principle of community self-reliance in the post-construction phase and discourage communities from making their own investments in water infrastructure to support economic growth.

Achieving long-term financial sustainability in these systems will require a different policy model. Methods for achieving better coordination of the policies of NGOs with government and with each other seem especially important and worthy of future research. One important role for NGOs in the future could be as catalysts for post-construction support (e.g., training and/or locally-based models for raising capital), rather than as dispensers of subsidies for communities that cannot manage to repair their own water projects.

In summary, the demand-driven, community-management planning model has come a long way towards a working model in the rural water sector. The next frontier seems to be the design of a policy framework that will enable communities to handle the twin challenges of system rehabilitation and expansion.

PART 1: INTRODUCTION

CHAPTER 1: INTRODUCTION[1]

Much is still unknown about how to design effective projects for village water supply. Past studies have examined pre-construction factors and shown that demand-responsiveness, community participation, and social capital in the village are all important determinants of success. But even projects with a high level of demand, high social capital, and high levels of pre-project participation can have problems after construction. The reasons include lack of availability of spare parts, lack of training, and an inability to raise funds for maintenance and repair. A program that provides post-construction support focusing on one or more of these common issues seems like a logical solution.

This volume reports the main findings from a multi-country research project that was designed to develop a better understanding of how rural water supply systems are performing in developing countries. We began the research in 2004 to investigate how the provision of support to communities after the construction of a rural water supply project affected project performance in the medium term, defined as the period of system operation three to twelve years after initial construction. We collected information from households, village water committees, focus groups of village residents, system operators, and key informants in 400 rural communities in Bolivia, Ghana, and Peru; in total, we discussed community water supply issues with approximately 10,000 individuals in these communities.

In the course of investigating the effects of post-construction support (PCS), we learned much about how rural water supply systems are faring in parts of the three countries studied. We believe these observations will be of broad policy interest to professionals in the water sector because they contradict the general perception that most rural water systems fail and that success depends on recovering costs through sizeable, ongoing contributions from users.

In this chapter we first discuss the evolution of approaches to rural water supply and post-construction support by government agencies or project authorities in developing countries and then, in Section 1.2, appraise the factors that influence the sustainability of such projects, particularly when communities themselves manage the projects. Section 1.3 of the chapter describes our research design, and Section 1.4 the fieldwork conducted for the country case studies in Peru, Bolivia, and Ghana. Part 2 of the volume contains these three case studies, and Part 3 draws together the findings and discusses their implications for the maintenance and expansion of rural water supply systems.

1.1 Approaches to rural water supply and post-construction support

In the 1980s it became widely recognized among sector professionals that many rural water supply programs in developing countries were performing poorly (Briscoe and De Ferranti 1988; Churchill et al. 1987; Therkildsen 1988). No matter what type of technology they relied on, systems were not being repaired and were falling into disuse. Cost recovery was minimal, and revenues were often insufficient to pay for operation and maintenance, much less capital costs.

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[1] This chapter was written by Alexander Bakalian, Jennifer Davis, Kristin Komives, Heather Lukacs, Linda Prokopy, Richard Thorsten, Wendy Wakeman, and Dale Whittington. Parts of it draw heavily on Lockwood (2003), which was commissioned for the present study. We appreciate the helpful comments of Rob Chase, Marc Jeuland, Donald T. Lauria, Vijayendra Rao, Robert Roche, and Jennifer Sara.

Communities did not have a sense of ownership in their water projects, and households were not satisfied with the projects that donors and national governments installed.

An intense discussion ensued within the water resources profession about why success in rural water supply was so difficult to achieve. Engineers blamed poor construction, anthropologists described a lack of community participation, political scientists reported rent-seeking and poor governance structures, and economists complained of poor pricing and tariff design.

Demand-driven, community management model for RWS projects

In the 1990s a consensus emerged that pre-project planning procedures for rural water supply programs needed to be more “demand-driven.” The necessary components of a demand-driven process differ somewhat depending on whom one asks, but most observers would agree that project planning should (1) involve households in the choice of technology and of institutional and governance arrangements; (2) give women a larger role in decision making than has been the norm; and (3) require households to pay all of the operation and maintenance costs of providing water services and at least some of the capital costs (Sara, Gross, and van den Berg 1996; Sara and Katz 1997; Whittington, Davis, and McClelland 1998). The rationale for involving households in the choice of technology was to ensure that engineering designs were responsive to local needs and realities. Women should assume a greater role in decision-making because they were the ones who best knew the local realities and were primary beneficiaries of the projects. Cost recovery through user fees served three purposes. First, requiring households to pay for services, once operational, provided revenues to keep the system running and reduced dependence on higher levels of government. Second, charging households (part of) the capital cost of system construction up front, before installing the water supply system, established a “demand filter” that in principle prevented water systems from being built in communities for which they were low-priority development projects. Third, requiring capital contributions by communities was expected to foster a sense of community ownership of the facilities, which in turn was expected to solidify a commitment to use and maintain the facilities.

The consensus on the need for a demand-driven planning model was largely silent on the relative importance of the components. Were all three components necessary for success? And was it possible to implement some elements first and follow up with others later? It was implicitly assumed that, if other elements of the model were present and spare parts were available for purchase, communities would take responsibility for managing and maintaining their water systems without further post-construction support.

The most controversial component of the policy advice in the demand-driven, community management model has been the requirement for households to pay a share of the capital costs, and all of the operation and maintenance costs, of providing rural water services. Three common arguments are made against charging poor rural households for improved water systems. First, in many cases the households that lack improved water sources are the poorest of the poor, and efforts to require such households to pay something for services (or efforts to target investments to communities that are collectively willing and able to pay) have often created unease among aid organizations working in the sector. Small NGOs such as church-based organizations and other charities, especially, want to help poor people in direct, tangible ways. Projects to provide improved water supplies to poor rural households have often received strong support from both NGO staff and their donor base, and requiring people to pay for such services has run counter to the rationale and desire of many NGOs to assist such communities. Second, the provision of improved water services is seen to have large positive effects on health: a traditional economic efficiency criterion calls for the use of a Pigouvian subsidy to equate marginal social benefits with marginal social costs.[2]

A third, and somewhat different, line of argument in support of providing improved water services free of charge is that poor households are caught in a vicious cycle of poor health, limited education, and low economic productivity, and that improved water (and sanitation) services are one change that helps people to break out of this "poverty trap" (Sachs 2005). From this perspective, subsidized rural water projects are not only equitable and morally obligatory, but also engines of economic growth. This argument for simultaneously investing in health, education, and infrastructure is reflected in the desire to meet the multisectoral Millennium Development Goals by 2015.[3] Although there is no firm evidence that investments in water supply projects induce economic growth in poor rural communities, the "poverty trap" metaphor resonates strongly with NGOs and other donors uncomfortable with the cost-recovery component of the demand-driven, community management model.

NGOs and multilateral donors have been more willing to shift nonpecuniary costs (such as time and labor commitments) on to community members. The demand-driven, community management model holds that much of the human resource cost of managing rural water projects should be transferred to village water committees (VWCs). This proposal has been relatively uncontroversial.

Since the mid-1990s a number of donors, working with national and regional water resources ministries in developing countries, have designed and implemented rural water supply programs that incorporate one or more components of the demand-driven, community management model.

Few of these programs planned for systematic provision of post-construction support; community management was assumed to be feasible from a technical perspective. Increasingly, however, observers have argued that it is unrealistic to leave rural communities to their own devices after a water project is completed, and that for rural water supply systems to be successful, communities need some PCS, such as follow-up training, and technical assistance visits by engineers (Blagbrough 2001; IRC 2001, 2003; Kleemeier 2000; Lockwood 2002, 2003; Rosensweig, ed., 2001; Schouten and Moriarty 2003).

As listed by Lockwood (2002:22), beyond technical support for the operation and maintenance of physical infrastructure, PCS has four main functions:

- Technical assistance: providing advice and guidance on a range of topics in support of the community management structure, as well as providing independent advice in cases where some form of arbitration may be necessary.
- Training: ongoing training of village water committee members in a variety of disciplines, from physical operation and maintenance to bookkeeping and hygiene promotion; capacity building at the community level.
- Monitoring and information collection: regular monitoring of system performance and feedback of information for remedial action.

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[2] The evidence for the existence of such positive effects on health from improved water supplies is, however, surprisingly limited. See Fewtrell et al. (2004) for a recent review.

[3] See <www.un.org/milleniumgoals> However, the need for *simultaneous* investments across sectors has not been widely accepted by economists. See, for example, Hirschman (1958) and Schumpeter (1939).

- Coordination and facilitation: helping to establish links between community management structures and external entities, from either the state or private sector.

Institutional models for post-construction support

Two broad approaches to providing PCS have emerged. The first, “demand-driven” approach is to ensure that spare parts and technical services are available, but to leave the responsibility largely to communities themselves to seek out such services and to pay for them when needed. The second is a more “supply-driven” approach: to provide communities with unsolicited support for repairs, technical assistance, training, and trouble-shooting.

Systematic post-construction support for communities has been rare, and few countries have adequate institutional frameworks to provide such support. Where such support arrangements exist, they focus largely on the operation and maintenance (O&M) of hardware, and aspects such as auditing of accounts and chlorination of water, and they tend to be overburdened. Very important non-technical issues such as ensuring the continued involvement of women, promoting sustained changes in hygiene behavior, and the protection of water sources tend to receive too little emphasis. (Because the broader benefits and potential impacts of rural water supply systems go far beyond a narrow technical focus, support services that do not also include “software” aspects cannot be considered fully successful.)

Several institutional models for post-construction support are in use (Box 1.1).

In practice, the choice of institutional arrangements for post-project support needs to be context-specific. In highly decentralized countries such as Bolivia and Ecuador, or in countries such as India where a decentralized approach to water and sanitation services is being actively pursued, it makes sense to provide technical assistance and build capacity at local levels. But in more centralized countries, such as Paraguay, Tunisia, or Yemen, local governments will have little to offer in terms of management capacity and decision-making authority. In many cases, the support mechanisms on the ground may combine different models. Further, the models are likely to evolve over time. Decisions about such arrangements are closely linked to broader sector reform and the status of the decentralization process in the country concerned. Clearly defined regulation in certain key areas, such as technical norms and standards and water quality, is a positive factor in the success and acceptance of models of support (Rosensweig, ed., 2001:134).

No clear lessons have emerged about whether or not PCS is better done by the project-implementing agency. Some of the more common experiences are described in Box 1.2.

In providing post-project institutional support arrangements, probably the single greatest challenge is financing their recurrent costs. Encouraging governments to contribute financially to support services in a resource-scarce environment will always be difficult: the product is not “visible” and not obviously useful as a political tool. Even where local government may be mandated to provide support service functions, such tiers of government often face many financial constraints. At the other end of the spectrum, over-reliance on external donor funding can endanger the sustainability of the entire support system, as happened in Honduras with the circuit rider model (Rosensweig, ed. 2001). Many RWS projects supported by World Bank loans depend on the private sector playing a specific role to complement the efforts of the public sector. But the private sector is unlikely to provide systematic support to rural populations where there is relatively little profit in so

Box 1.1: Institutional support mechanisms for post-construction support

The Environmental Health Project has classified institutional support mechanisms for PCS based on case studies in Latin America (Lockwood 2002; Rosensweig 1998; Rosensweig, ed., 2001; Rosensweig and Perez 1996):

- **Centralized model:** Support services are provided by a government agency or ministry operating from a centralized point, directly engaging with community management structures. Until recently, this model of support was used in Costa Rica, where the Directorate of Rural Works of the Costa Rican Institute of Water Supply and Sewerage provided back-up coverage from a central operation based in the capital to six administrative zones of the country. A deconcentrated model with six regional offices has recently superseded this system.
- **Deconcentrated model:** Support services are provided by a central government agency operating through regional or departmental level offices that have a degree of autonomy. Morocco uses a deconcentrated model with teams operating at the provincial level. In Honduras the National Water Supply and Sewerage Company has a nationwide system of deconcentrated support offices, based on the circuit-rider model whereby a technician on a motorcycle visits a number of rural communities on a regular basis and dispenses advice and technical know-how; these technicians now provide support to more than two million Hondurans in rural areas.
- **Devolution model:** The authority and responsibility for provision of support services is transferred from a central government agency to a decentralized tier of government, usually at the municipal level. In various regions of Nicaragua, the Rural Water Supply Management of the Nicaraguan Water Supply and Sewerage Company (ENACAL-GAR) has worked with municipal authorities to develop networks of municipal operation and maintenance promoters. Because they work with technical oversight from ENACAL-GAR operations staff based in regional offices, this model is best described as a deconcentrated—devolution hybrid. In Ghana, district government teams provide oversight but also receive support from decentralized central ministry offices at the regional level. In Bolivia, municipal governments are responsible for long-term support under a devolution model, but also receive support from deconcentrated central ministry offices. In China, municipal or county governments operate and maintain systems under a devolution approach.
- **Delegated model:** Responsibility for provision of support services is delegated (by contract) from a central or local government agency to a third party, which could be an NGO, a private company, or a relevant user association. The Honduran Water Board Association is a delegated support system operating in approximately 300 member communities.

Source: Adapted from Lockwood (2002:14)

doing; ultimately, the test of its participation will lie in the willingness of users themselves to pay for post-project support goods and services.

Working in support of rural communities requires agency staff with a range of skills and attributes covering technical, social, and financial aspects, as well as themes such as hygiene education and conflict resolution. Political interference and frequent changes in personnel can easily cause difficulty in post-construction support services. Other factors influencing success include a supportive policy environment.

1.2 Assessing sustainability in rural water supply

There is little systematic evidence as to how the demand-driven, community management model—with or without PCS—is working in practice. Are projects that use the demand-driven, community

Box 1.2: Assigning institutional responsibility for post-construction support

- **Project partner (NGO or private company) as implementer and local government as provider of support services.** In several World Bank-supported projects in Latin America, the same NGO or contractor responsible for constructing systems and/or providing software implementation services is held responsible for the post-construction "guarantee period." After this period, primary responsibility for indefinite back-up support is most often transferred to the municipality (equivalent to local government) authorities, with or without assistance from other players. The municipality is also involved in project implementation, but usually in a management or co-financing capacity. In a World Bank-supported community water supply project in Sri Lanka, systems are constructed and training is provided by NGOs or private companies contracted by the project, but local government will eventually share responsibility for support and oversight of the community-based organizations running the rural systems.
- **Central government as implementer and provider of support services.** In Paraguay, the National Environmental Sanitation Service (SENASA) was responsible for both construction and long-term support, based on a centralized model of service delivery, but problems with this model led the government to look at other options for back-up support, such as encouraging private sector involvement and facilitating the formation of associations of water committees. In countries including Morocco, Rwanda, and Yemen, central water ministries have been responsible for system construction and then for back-up support, but with a strong emphasis on the complementary role of the private sector. Tunisia relies on deconcentrated offices of a central ministry (Rosensweig, Stanbury, and Grimm 1990), and Costa Rica has deconcentrated its rural directorate of the central Water Supply and Sanitation Agency into six regional offices (Lockwood 2002). Both these countries have put responsibility for implementation (or oversight of implementation) and long-term post-construction service in the hands of single ministries. In Honduras, too, post-construction services are provided by the project implementing institution.
- **Central government as implementer, delegating support services to a third party.** In several cases, central government agencies were initially responsible for system implementation but then delegated responsibility to a third party for long-term support. In some areas of Paraguay, multi-community associations of water committees are taking responsibility for long-term service provision, and elsewhere in that country private companies are taking on minimum subsidies to operate and maintain piped rural systems.

Source: Adapted from Lockwood (2002:14)

management approach being sustained? What influences their sustainability and how are these influences best measured?

Definitions of sustainability

Early discussions of sustainability in the water supply and sanitation sector were concerned mainly with the financial aspects of service delivery and the need to make projects financially self-sufficient (see Black 1998).

Subsequent discussions of sustainability have taken a broader view, centered on the concept of the capacity of a RWS project to continue delivering a flow of benefits long after project inputs have ceased (Bamberger and Cheema 1990; Hodgkin and WASH Project Staff 1994:5; Valadez and Bamberger, eds. 1994) or "after the withdrawal of all forms of support from the external agency" (CINARA/IRC/WSP 1997). Many authors have built from this basic idea, noting that the concern is not so much with the project per se, but rather with the water supply (and/or sanitation) system itself and the service it provides (Carter, Tyrell and Howsam 1999; Sara and Katz, 1997;

Webster et al. 1999). For many rural households, the perceived benefit of a project may simply be the continued convenience of having (running) water near or within the household. Hence, their definition of sustainability may be closer to meaning whether or not water continues to flow to them over time.

With the growing importance of the community management model for RWS, sustainability has also been defined in terms of the *capacity of the community itself* to maintain the service (IRC 2001). But, as noted above, authors have increasingly argued that few communities will be able to manage their own water supply systems without some form of external assistance, and the need for such support is now gaining broad acceptance. Thus, classifying a community-managed RWS system as sustainable should not preclude the community from having access to continuous, external back-up support of some kind.

Factors influencing sustainability of community-managed RWS projects

Taken together, a few studies offer some broad insights about factors that commonly influence sustainability in rural water supply (Hodgkin and WASH Project Staff 1994; Sara and Katz 1997; Sugden 2003);

- *Pre-project issues*

Community participation
Demand-responsive approaches
Empowerment
Technical design
Construction quality
Gender and poverty focus
Training

- *Post-project issues*

Finance and tariff collection
User satisfaction
Capacity of water committees
Definition of roles and responsibilities for system management
Ongoing training

Evidence from a wide range of literature and project documentation suggests that in community-managed RWS projects, five main groups of factors affect post-project sustainability:

- Technical factors, including design, performance, and maintenance issues.
- Financial factors, including the ability to cover recurrent costs.
- Community and social factors, including willingness to support projects.
- Institutional factors, including policy and external follow-up support.
- Environmental factors, including the dependability of the water source.

The two most prominent determinants of sustainability in community-managed RWS appear to be *tariff collection to cover recurrent costs* and the presence of *some form of long-term external support*. As a World Bank evaluation report states: "Sustainability can only be ensured if tariffs generate enough resources to operate the system, finance the expansion of the service to new customers, and ultimately replace the infrastructure after its useful life" (World Bank 1999: iv). Some form of long-term external support is also clearly critical to post-project sustainability. Such support can help communities face a range of challenges, including technical problems, organizational difficulties, and social conflict.

The second tier of factors influencing the sustainability of community-managed rural water supply projects includes preventive maintenance and spare parts availability; community management capacity, user satisfaction and willingness to pay for services; continued training and hygiene education interventions; and water source production and quality.

Some of the main factors affecting sustainability can be considered as "internal" to a community, and therefore at least partly within its sphere of influence. These are:

- Preventive maintenance of facilities.
- Tariff collection and cost recovery to cover routine operation and maintenance of water supply infrastructure.
- Adequate capacity (technical, financial, administrative etc.) within the community to manage a system, or to engage with an external party to operate and manage the system on its behalf.
- The continued involvement of community women, along with men, in all aspects of system management and maintenance.
- Adequate social cohesion or social capital to manage the system, and adequate motivation or willingness to contribute the necessary time and money.[4]

Factors that are seen to be largely "external" to the community are:

- Access to, or availability of, spare parts, tools, and equipment for the community to carry out repairs.
- The availability of some form of external follow-up support, not only to help empower community management structures to maintain the infrastructure they are responsible for, but also training for households to promote hygiene and behavioral change.
- The presence and strength of private companies and entrepreneurs[5] providing goods and services and skilled technicians to carry out complex repairs.
- The existence of a supportive policy environment, legal frameworks underpinning the legitimacy of water committees, and clearly defined roles for operation and maintenance.
- A system source that continues to produce water of sufficient quantity and quality to satisfy users.[6]

Distinguishing between "internal" and "external" influences on the sustainability of community-managed RWS projects is useful for analytical purposes but is somewhat arbitrary. Several of the internal elements are linked with (and, to a certain degree, conditional on) external factors being in place. For example, adequate management capacity of community structures may be correlated with continued technical support and training in key areas over time. Likewise, the success of cost-recovery efforts, as a key post-project determinant of sustainability, may be influenced by the extent to which individuals and committees are supported, re-trained, and guided in relation to tariff structures and broader financial management. Without such external guidance, cost-recovery efforts may slowly weaken, and perhaps be unable to keep pace with the costs of system expansion or replacement of major system components. Clear and widely disseminated national or regional rules and regulations will also benefit community management and tariff collection efforts. Like cost recovery and community management, women's long-term involvement in the

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[4] Among this list of factors, these are perhaps the most abstract and difficult to define or measure, although there is now a growing body of knowledge about this can be done (for example, see World Bank 2002).

[5] The private sector is defined here as including NGOs as well as individual artisans and entrepreneurs ranging from one person on a bicycle serving 30 handpumps, all the way through to small companies providing maintenance contracts for piped systems with household-level connections.

[6] Obviously, deterioration of source water quantity will be of major concern in areas of low rainfall, or poor groundwater re-charge, where there is greater sensitivity to over-extraction. But even where water is relatively abundant, a source can fail to satisfy demand, whether because of population expansion, abuse of the supply for non-domestic purposes, or contamination from agricultural by-products or chemicals.

management of RWS project benefits can be influenced by external factors. Especially in cultures where the role of women is strictly limited, it often happens that once the interventions of project staff finish, any gain in women's involvement falls back, or is given only token recognition. Anecdotal evidence suggests that the long-term involvement of women can be facilitated by the continued, if infrequent, intervention of a "trusted" outsider.

1.3 Research design

It is important to understand our initial research design in order to appreciate the strengths and limitations of the findings presented in this volume. We wanted to investigate the effect of post-construction support on system sustainability when added to a well-designed, demand-driven, community managed rural water supply program.[7]

A gold-standard research design for such an investigation would consist of a randomized controlled experiment in which baseline conditions would be measured in villages, all of which had received an improved water system as part of such a well-designed rural water supply program (Baker 2000). Subsequently, post-construction support would be randomly assigned to treatment villages but not to control villages, and then any differences in treatment and control villages could be confidently attributed to the PCS intervention.

We did not have the time or resources to follow this approach. The best we could do was to try to find situations where some villages had received PCS and other similar villages had not.[8] In order to establish the direction of causation between PCS and system performance, we needed to find well-designed rural water supply programs in which some villages (i.e., the treatment villages) had received PCS without asking for it and other villages (the control villages) had not. Therefore, in the design stage of the research project we searched for rural water supply programs in developing countries around the world that used a "state of the art" demand-driven, community management model and also used a supply-driven (automatic) PCS program to assist villages after construction. Demand-driven, community managed rural water supply programs that have been in operation for several years are not common, and such programs with supply-driven PCS components are rare around the world. We selected programs in Bolivia, Ghana, and Peru that we believed came closest to meeting these research design criteria. As a result, our research design led us to study donor-funded rural water supply projects, and thus communities that were not randomly selected from either a global or country perspective.

In all three countries, our sample villages had received improved water supply projects three to twelve years earlier as part of a demand-driven, community managed, and donor-supported rural water supply program. About half the villages were treatment villages—that is, they had received some forms of post-construction support arranged by the RWS program and half were controls—that is, they had not received any such support. In all three countries, we used secondary data to help us choose districts or regions where the characteristics of villages and households in the treatment and control villages were likely to be similar.

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[7] It did not seem interesting to study the effect of PCS in poorly designed programs because there is ample evidence in the literature (e.g., Narayan 1995; Sara and Katz 1997) that these programs would have many failures and that PCS alone could not salvage them.

[8] Nor did we have the time or resources to measure baseline conditions in treatment and control villages, and then wait for the effects of the treatment (PCS) to unfold. Rather we collected information from both treatment and control villages in the current period, after some villages had received PCS. Because of this, we were forced to ask people we interviewed today about conditions in the past, both before and after their rural water system was constructed. This approach is not ideal because people's memories are imperfect and some baseline data simply were not available to us.

In Bolivia, both the treatment and control villages were part of PROSABAR (*Proyecto de Saneamiento Básico Rural*), a rural water supply and sanitation program that grew out of a Water and Sanitation Program pilot project supported by the World Bank. We selected 99 PROSABAR villages in the Chuquisaca and Cochabamba departments. Sample villages were located in the central highlands at elevations of 1,800–3,000 meters, where rainfall varied from 30–69 centimeters per year. Within each of these two departments, we sought to cover about 25 communities that had received some form of PCS under PROSABAR and another 25 that had not. However, the determination of "treatment" and "control" communities was problematic because the municipal records regarding the provision of PCS were often incorrect. Communities were later reclassified into the "treatment" or "control" group based on interviews, reports, and records related to PCS in each community. We ultimately studied 99 communities; 50 in Chuquisaca and 49 in Cochabamba.

In Peru, both treatment and control villages were in the Cuzco region. The 43 treatment villages were part of the Swiss-funded SANBASUR program, which provided PCS; the 56 control villages were supported by the World Bank-financed FONCODES social investment fund, which distanced itself from projects after their completion. As in Bolivia, the sample villages in Peru were in the central highlands, though their elevations were slightly higher (2,500–4,000 meters); annual rainfall was about 70 centimeters. The average village size in Peru (588 people) was a third smaller than in Bolivia (870 people).

In both Peru and Bolivia, the rural water systems studied were almost all gravity-fed piped distribution systems with unmetered private connections; in some villages a few public taps were installed for unconnected households. At the time of the fieldwork, the systems in these two countries were on average seven years old. Capital costs in Bolivia were approximately US$80 per capita at the time of construction (US$400 for an average household with five members); costs in Peru were probably comparable.

In Ghana, the "treatment" villages were selected from four districts of Volta region and the "control" villages from five districts in the Brong Ahafo region. The treatment villages had received their water supply projects through a Danida-funded rural water supply program that, since 2003, included a PCS component called Monitoring of Operations and Maintenance (MOM). The control villages in Brong Ahafo had taken part in a community water supply program supported by the World Bank that did not seek to provide PCS. Both treatment and control villages were in lowland forest at elevations of 74–503 meters, where annual rainfall was about 120 centimeters. The average age of the water systems in sample villages in Ghana was six years. Only villages with boreholes and non-mechanized public handpumps were included in the sample. We limited the sample of both control and treatment villages to communities that had received no more than two boreholes as part of the water supply program. This effectively also limited the size of the villages that we included; at the time of our field visits in 2005 the population of sample villages ranged from 200 to 5,000 people. These selection criteria yielded a potential sample frame of 98 villages in Volta and 120 villages in Brong Ahafo. All 98 Volta villages were selected, and 104 out of the 120 Brong Ahafo villages were randomly selected.

Field conditions in all three countries presented some unanticipated challenges. Our research design required that the water systems in some villages be "successes" and in others "failures" in order to have variation in our dependent variable. In fact we found far fewer project failures in either treatment or control villages than expected.

Another threat to our research design was the complexity of PCS provision in the study settings. As explained above, we tried to identify PCS programs that were supply-driven, but we found that even supply-driven PCS programs often do not work that way in practice. The MOM program in Ghana turned out to be the only true supply-driven PCS program in our three study sites: villages in this program received quarterly visits from environmental health assistants to monitor the technical, management, and financial status of their rural water supply systems. More commonly, we found that communities in the three countries were seeking out PCS when their water systems broke down or when there was a management problem or conflict.[9] We also found that communities could often get help from more than just one source, including NGOs, nearby municipalities, or even large commercial enterprises, and that some villages may have had the political clout to obtain financial assistance from a member of parliament or a wealthy relative of a village resident living abroad. Thus, even in villages that took part in PCS programs that were designed to be supply-driven, in practice much PCS was demand-driven, in the sense that many communities sought help from wherever they could get it. Many of the control villages (villages without supply-driven PCS) in our study sites had various demand-driven forms of PCS available to them.[10] In any well-designed demand-driven, community managed rural water supply program, at least initially, even villages without PCS have access to spare parts and to some technical expertise (even though, for a variety of reasons, these villages might not retain or mobilize to use the training or procurement systems that were put in place at the time of project construction).

To sum up, though our research question was whether post-construction services supplied by government would improve the performance of village water systems, the baseline condition in the control villages was never *no* PCS. The implementation of our initial research design revealed the complexity of causal connections between PCS and system performance.

1.4 Data collection and profile of sample villages

Our fieldwork began in Peru in the middle of 2004, in Ghana later in 2004, and in Bolivia in early 2005. Data collection activities in each country were similar, but not the same. Generally, a data collection team spent one day conducting the fieldwork in each village. In the course of a day, the team held a group interview with members of the village water committee, interviewed the water system operator or caretaker (and borehole attendant if applicable), conducted a focus group with women from a diverse set of backgrounds, ages, ethnic, and income groups, and administered surveys to the heads of household (or spouses) in approximately 25 households.

In Bolivia, we worked with leaders to draw community maps and selected random samples of households. In Peru and Ghana, enumerators were scattered more or less throughout a village and were instructed to interview every fifth household or follow some other similar sampling rule. In Bolivia and Peru, interviews were conducted in either Spanish or Quechua; in Ghana in either Twi or Ewe. In addition to the survey and focus group information collected by the fieldwork teams, technical staff made an engineering assessment of the water supply system in each village. In Peru and Ghana, data collection also included a focus group discussion with village leaders. In Ghana, the most heavily used borehole in each village was observed for one day, and data were

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[9] Given the choice of sending technical personnel to a community that has requested assistance and another community that is due for a regularly scheduled check up visit, but is presumed to be doing well, it is natural for a manager of a PCS program to be inclined to direct resources to where the problem is.

[10] Especially with the public handpump technology used in Ghana, breakdowns are to be expected and repairs are often necessary. Control villages must be able to obtain spare parts and mobilize the technical expertise necessary to make repairs. Without these, *all* handpumps in villages in a rural water supply program (and some gravity-fed distribution systems as well) will be out of service after only a few years.

collected on the quantity of water obtained. Most of the information used in the three country studies comes from the interviews with village water committee members, water system operators, and households.

Our fieldwork showed that the sample villages in Bolivia and Peru were small and remote; in Ghana they were on average larger and more accessible. Most of the sample villages in Peru and Bolivia had electricity, and many households were connected directly to this service. In Ghana, only 32 percent of the sample villages were connected to the electricity grid. In all three countries, the majority of households reported that they were farmers. Average education levels were low; the typical respondent in all three countries reported having had "some" primary education. In Peru, 60 percent of the households who were interviewed reported annual cash income of less than US$150 (vs. 42 percent in Bolivia). In Ghana, households reported median monthly cash expenditures of about US$57. The average household had five members in Peru and Bolivia (vs. six in Ghana). High percentages of households in Bolivia (86 percent) and Ghana (75 percent) reported trusting their neighbors (vs. 51 percent in Peru).

PART 2: COUNTRY CASE STUDIES

CHAPTER 2:
POST-CONSTRUCTION SUPPORT AND SUSTAINABILITY IN RURAL DRINKING WATER PROJECTS IN CUZCO, PERU[11]

Summary

Peru is one of the few countries in the world to have an active program for post-construction support covering enough villages to enable quantitative analysis. Of the 99 villages included in our study, about half took part in a rural water supply program that was designed to include post-construction support (PCS) while half received a water project with no intentional PCS. We find that, in practice, both the programs provided demand-driven PCS. Water systems in both groups of villages were performing remarkably well at the time of our fieldwork: most of the private taps were functioning, consumers were using the systems and were largely satisfied, and most consumers believed the systems would still be functioning in five years' time. The lack of variation among some of our dependent variables made it difficult to assess the importance of PCS overall. Village water supply systems in Cuzco were likely to be functioning whether or not they received PCS. Many of the sampled communities had delivered water consistently over 10–15 year periods without PCS, and though many systems broke down, communities had often been able to mobilize resources to get them running again. A smaller set of communities whose water systems were not functioning as well were demanding post-construction support more frequently. This suggests that post-construction assistance would prove most beneficial to communities that are struggling with intermittent service, limited coverage, and frequent breakdowns.

2.1 Introduction

In this case study our main hypothesis is that the sustainability of a village water supply system is linked not only to the existence of specific conditions and factors before and during construction, but also to specific factors well beyond the end of construction. To examine the role of post-construction support (PCS) in sustainability, we analyzed the experience of nearly 100 villages in Cuzco Department that implemented a water project between 1993 and 2001 with help from either of two funding sources: FONCODES, Peru's national social investment fund, and SANBASUR, a program funded by the Swiss development agency COSUDE. Unlike FONCODES, which has no explicit goal of supporting projects after completion, SANBASUR has provided short-term post-project support in conjunction with local governments.

Choice of study area

Only two of Peru's 24 political departments, Cuzco and Cajamarca, have post-construction assistance programs for village water supply projects. In Cuzco, SANBASUR is the only program with an emphasis on post-construction. Initially, we also considered studying two programs in Cajamarca—PROPILAS and APRISABAC—but found that neither of these met our requirements of focusing specifically on water supply and of having implemented projects that were mature enough for an assessment of sustainability.

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[11] This chapter was written by Linda Stalker Prokopy and Richard Thorsten. The authors would like to thank Eugenio Bellido, Brenda Bucheli, Rob Chase, Jennifer Davis, Jorge Izaguierre, Marc Jeuland, Kristin Komives, Jennifer Sara, Rafael Vera, Dale Whittington, FONCODES and SANBASUR officials, and especially all of the field coordinators and enumerators who helped make this study possible.

Most of Cuzco's 13 provinces lie in the mountainous Sierra Sur region, where the river valleys range from 2,500–5,000 meters in height. Most villages obtain their water from rivers, lakes, and springs set near the mountain peaks.[12]

Programs evaluated

Both SANBASUR and FONCODES strive to reduce poverty, respond to local demand, encourage community participation, and encourage self-sufficiency through training for new village leaders and household members. Both programs have emphasized community participation and demand-responsiveness before water supply projects commence, and local committee management after the water systems begin to function. Both programs have used intermediaries to fund their projects, albeit through different mechanisms.

FONCODES is the principal investment arm of the Peruvian rural water supply sector and is responsible for much of the growth in piped water supply in Peru's rural areas. The fund invested $361 million in rural water supply during the 1990s. FONCODES transfers responsibilities for completed investments to the community and does not offer defined post-project support. Once a project is complete, a *nucleo ejecutor*—a group established by the community to work with FONCODES during planning, construction, and transfer of water project—operates the project for six months. During this time, an inspector-resident ensures that villagers have received enough training and that a new organization elected by the community is ready to assume full responsibility for the project. FONCODES then transfers legal responsibility for the project to a *junta administradora servicios saneamientos* (JASS)—an administrative committee created by the village—which replaces the *nucleo ejecutor*. FONCODES' official role ends with the transfer.

The Swiss-funded SANBASUR (*Saneamiento Basico en El Sierra Sur*) currently works only in Cuzco Department. It collaborates with the Ministry of Health, CTAR (the transitional regional government of Cuzco), local district governments, NGOs (which serve as executing interlocutors for projects), and local communities. SANBASUR provides basic water and sanitation services, stressing training for village water committees, hygiene education, and system construction, and strengthens the institutional capacity of municipal districts, village water committees, and their counterparts. SANBASUR constructed 141 projects, benefiting 50,000 people, over the period 1996–2000 in four Cuzco provinces; it subsequently expanded to three other provinces and had completed 238 projects as of June 2004.

SANBASUR's training and capacity-building activities have evolved since the program began in 1996. Today, JASS organizations are monitored for six months after project completion to determine whether they are capable of taking on full management responsibilities. After the final transfer, MINSA employees are responsible for monitoring water quality, while local governments are responsible through their contracts with SANBASUR for working with the JASS groups on ongoing system needs. SANBASUR produces operation and maintenance and educational manuals for every village. On written request, it also provides additional technical support and training for the JASS groups, though it encourages communities to solve their problems independently or with local government assistance before contacting the program authorities. Only seven communities had requested this follow-up assistance from SANBASUR at the time of writing. Villages can also rely on assistance through partnerships they establish with NGOs and local governments as a result of the program.

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[12] The major exception in the region is La Convencion province, which slopes northwest into the Peruvian rain forest basin of the Amazon River; this province was excluded from our analysis due to its geographic and hydrological differences from the rest of Cuzco.

Thus, whereas FONCODES has distanced itself from projects after their completion, SANBASUR has provided short-term post-project support in conjunction with local governments. Like FONCODES, however, it has also encouraged self-reliance among its client communities, urging them to collaborate with local ministries of health and education and local governments. Table 2.1 summarizes key similarities and differences between the two programs.

Outline of study

The remainder of this chapter is organized as follows. Section 2.2 describes the approaches used for sample selection and data gathering. Section 2.3 reviews the attributes of the villages with FONCODES and SANBASUR projects and compares the experiences of the two groups. Section 2.4 uses bivariate analysis to look for correlations between indicators of project sustainability and likely determinants of sustainability. Section 2.5 uses multivariate regression analysis (ordinary least squares and logit models) to examine the relationships between sustainability and different types of post-construction support, and Section 2.6 concludes.

2.2 Sampling frame and data gathering

Data were collected from fieldwork in 2004 and 2005 pertaining to SANBASUR and FONCODES projects completed between 1993 and 2001. Though for the youngest of these projects the period since completion is too short for a reliable assessment of sustainability, it is long enough to provide preliminary indications for this purpose.

Table 2.1: Key similarities and differences in FONCODES and SANBASUR programs

Program characteristic	FONCODES	SANBASUR
Community initiation of project	Yes	Yes
Pre-project community participation required	Yes	Yes
Community contributions encouraged/required	Yes	Yes
Women's participation encouraged	Yes	Yes
Gravity-fed water system technology	Yes	Yes
Operator & water committees trained before operation	Yes	Yes
Private connections built	Yes (post-project)a	Yes
Written materials provided	Yes	Yes
Water management committee organized during project	Yes	Yes
Operation and management transferred to water committee	Yes	Yes
Non-water and sanitation projects available	Yes	No
Exclusive focus in Cuzco Department	No	Yes
Post-construction support offered by program or via interlocutor agency or local government	No	Yes

Source: Author(s)

[a] FONCODES did not install private connections. However, a 2000 evaluation of FONCODES water projects noted that 52 percent of households surveyed did have private connections. Households or communities probably built these connections after the transfer of the projects (OED 2000)

In each of the villages studied, data were collected from an interview with a system operator, focus groups with both village leaders and women, a survey of 25 households, and a technical assessment of the system, which was performed by an engineer.

Sampling frame

We focused on Cuzco villages that were large enough to operate their own systems and small enough not to qualify as municipalities. Both SANBASUR and FONCODES provided us with lists of the villages to which they had provided water services, complete with information on the dates when construction was completed and the number of project beneficiaries in each location. We used this information to select villages that ranged in size from 400–2,500 people. All the projects within our sample frame were gravity-fed water schemes—the dominant system type in Cuzco. Our initial sample of 99 villages represented all 56 FONCODES and all 43 SANBASUR villages that met our criteria.

The first phase of fieldwork was completed in September 2004. During this phase the field coordinators realized that some of the villages on the FONCODES list had not in fact received water projects through this investment program. The consultant, PACT Peru, worked with the research team to find substitutes to include in our sample, but we were left with fewer villages than we needed for statistical rigor. Substitutes also had to be found for a few SANBASUR villages in which enumerators had failed to obtain meaningful data.

Due to these issues, a second round of fieldwork was undertaken in June 2005. The research team and consultant worked together to replace 20 visited villages in the sample with 20 other communities that had received water projects under either FONCODES or SANBASUR. We received a new list of villages from FONCODES and (to increase comparability) removed all villages in provinces where SANBASUR does not work. As we had already exhausted all the SANBASUR villages with more than 400 residents, we enlarged our sampling frame to include villages with between 350 and 400 people. We also eliminated FONCODES villages that were larger than 1,500 people (since the largest SANBASUR village in our sample had 1,470 people). We then randomly selected villages from the new sampling frame.

A few communities in our sample received both FONCODES and SANBASUR projects. For analytical purposes, they are considered SANBASUR villages, because SANBASUR entered these communities after they had completed their FONCODES projects.

Survey instruments

The questionnaires for Peru were the first to be developed of the three countries studied in this volume. They were:

- *Household Survey.* Administered by enumerators to 25 households in each village, this survey covered current and pre-project water use practices, household participation and attitudes about the planning, implementation, and ongoing project, infrastructure uses, social capital questions, and socioeconomic information about the household.[13] Overall, there were 1,360 male respondents and 1,089 female respondents to the household questionnaire.

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[13] Enumerators were trained to first attempt to randomly select households from a complete list, if available, or divide villages into equally sized neighborhoods with different water access and economic characteristics. If neither of these options was available, the field teams divided villages into geographic areas and assigned enumerators to randomly select every nth household depending on village population. In practice, this last option was used most frequently. Appendix 2.1 provides a summary of these techniques excerpted from the enumerators' training manual.

- *System Operator Survey.* Administered by an engineer to the primary system operator in each village, this survey focused on system functioning and attributes, forms of post-construction support received, operators' roles and responsibilities, and other activities. A final section was completed by the engineer to report on the physical condition of the water system.
- *Focus Group with Village Leaders.* Within each village, a focus group brought together formal and informal leaders in the community. Questions centered on village attributes (size, distance, socio-economic status, etc.), participation during the planning and construction phases, attitudes about the performance and quality of the water system, and the degree of social capital in the village. Groups typically contained five to ten people and were administered by the field coordinator.
- *Focus Group with Women.* A separate focus group convened women of different ages, ethnicities, and social status in the village. Female enumerators were trained to administer this survey. Women were asked about their water use and satisfaction with the water they were receiving. Other questions on participation and post-construction were similar to those in the surveys of leaders and water committees, to enable us to triangulate some of the results.
- *Focus Group with Village Water Committee (VWC).* Administered by the field coordinator, this survey of resident water committee members focused on membership structure and dynamics, forms of external assistance the village was receiving to keep its system functioning, attitudes about operation and water quality, and other forms of infrastructure. Field coordinators also located VWC members who were engaged during the planning and construction phases and questioned them about those phases of the project.

Field work activities

Field teams, each consisting of a field coordinator and four enumerators, spent one day in each village conducting all the surveys. Enumerators spoke either Spanish or Quechua during their interviews. An engineer separately visited each village to interview the system operator and examine the facilities.

As noted above, a second round of fieldwork was undertaken in mid-2005. The teams succeeded in obtaining data in nearly all of the cases.

2.3 Profile of the villages and their water supply systems

This section compares the experiences of villages with SANBASUR and FONCODES projects. After reviewing the basic characteristics and pre-construction experiences of the two groups of villages, it compares the types and amounts of post-construction assistance the villages received and then looks at four dimensions of project performance that seem likely to influence project sustainability.

Village characteristics

There are some notable differences between the two groups of villages. SANBASUR villages are much more isolated than FONCODES villages (on average, they are more than 60 km from the nearest paved road) and they have less access to electricity, lower incomes, and lower education levels; they also have higher social capital, on average, than FONCODES villages (Table 2.2).

Pre-construction factors

Table 2.3 illustrates the experience of the two groups of villages during the pre-construction phase. We know from previous sector studies that pre-construction factors can have large and significant

Table 2.2: Village characteristics: FONCODES and SANBASUR

Measure	Data source	FONCODES Average	SANBASUR Average	Anova p-value
System age	Household	7.57 years	6.13 years	0.007[a]
Number of households in village	Leaders	176	194	0.446
Number of people in village	Leaders	776	724	0.702
Nearest paved road (km)	Leaders	13.6	62.1	0.000[a]
Distance to river or stream (km)	Leaders	1.86	5.89	0.013[b]
Percent Mestizo in village (ethnicity)	Leaders	76.7	93	0.012[b]
Land ownership (topos)c	Household	3.34	2.72	0.131
Percent households with electricity	Household	73.5	44.6	0.000[a]
Cash income (range 1–4; 4 is highest)	Household	2.41	1.98	0.007[a]
Education level head of household (range 0–9; 9 is highest)	Household	2.45	2.14	0.040[b]
Education level spouse household head (range 0–9; 9 is highest)	Household	2.61	2.26	0.031[b]
How much do people in this community trust each other in terms of money (range 1–3; 3 is most trust)	Leaders	1.8	2.07	0.027[b]

Source: Author(s)

Note: In this and all the tables in this section, we present averages for both FONCODES and SANBASUR villages and then the p-value for the F-statistic in a one-way analysis of variance test (Anova). For the household data, the mean of continuous variables is used as a village variable, while for village-level data we have used the median of ordinal variables. A significant p-value indicates that the averages for FONCODES and SANBASUR villages are statistically different.

[a] Difference between villages is significant at less than .01 level.

[b] Difference is significant at less than .05 level.

[c] Approximately 3 *topos* = 1 acre of land.

impacts on project sustainability and effectiveness. Both the FONCODES and SANBASUR programs put a broad emphasis on demand-responsiveness and community participation in decision-making during the pre-construction phase. According to data from the leaders' and the women's focus groups, FONCODES and SANBASUR villages had similar pre-project discussions of key decisions. However, our household-level evidence shows that SANBASUR villages were generally more involved in pre-construction: they received significantly more training, they contributed significantly more days of labor, a greater percentage of households contributed labor, they were more aware of the project before construction began, and they attended more meetings than their counterparts in FONCODES villages.

Post-construction support

As expected, SANBASUR villages received more post-construction support than FONCODES villages (Table 2.4); operators in SANBASUR villages reported higher levels of most types of technical support and were significantly more likely to have attended training workshops or to have received written manuals or materials. Thirty-two percent more households in SANBASUR

Table 2.3: Pre-construction factors

Measure	**Data source**	**FONCODES Average**	**SANBASUR Average**	**Anova p-value**
Pre construction training [%of villages]	Household	29.7%	52.3%	0.000[a]
Number of decisions discussed pre-construction (out of total of 14 options presented)	Leaders	9.07	8.89	0.873
Labor payments (average days)	Committee	10.89	25.5	0.000[a]
Percent households contributed labor	Committee	78%	97%	0.514
Score for pre-construction participation[c]	Committee	34	34.7	0.567
Total amount of women's participation [c]	Women's Group	20.96	20.90	0.965
Number of days of labor contributed	Household	18	30.1	0.000[a]
Aware of project before construction began	Household	89.7%	95.1%	0.035[b]
Sum of participation scores[c]	Household	40.3	54.6	0.000[a]
Meetings attended pre construction (range 0–4; 4 is attended more than 10 meetings)	Household	2.18	3.03	0.000[a]

Source: Author(s)

[a] Difference between villages is significant at less than .01 level.

[b] Difference is significant at less than .05 level.

[c] Defined as the sum of values for a set of twelve questions concerning the level of community participation on a series of project decisions. This table appeared in every survey except the System Operator's Survey.

villages reported receiving some form of post-construction training pertaining to the water system. But overall, while SANBASUR villages generally received more post-construction support than FONCODES villages, they did not receive large amounts of such support.

Interestingly, FONCODES villages were more likely than SANBASUR villages to report that they had received spare parts (although this is a statistically insignificant difference) and more likely to have ever requested technical assistance. Committees in FONCODES villages also reported that they received more in-person visits to help with repair and maintenance. This finding is quite surprising. FONCODES was not designed to automatically *supply* post-construction support such as training. However, a handful of FONCODES villages were clearly *demanding* post-construction support and receiving it at the operator and committee levels.

Project performance

Below we compare the experiences of FONCODES and SANBASUR villages with respect to four components of project performance: physical performance, consumer satisfaction, financial performance, and perceptions of future sustainability.

Physical performance

In most other water supply projects we are familiar with in the developing world, a large number of private taps fail shortly after projects are constructed. Yet in both groups of villages, the systems

Table 2.4: Post-construction support

Measure	Data source	FONCODES Average	SANBASUR Average	Anova p-value
Technical support through in-person visits	Operator	19%	26%	0.463
Technical support through operator attending training workshops	Operator	27%	47%	0.048[a]
Technical support supplied through written manuals/materials	Operator	13%	30%	0.047[a]
Technical support through spare parts provided to village	Operator	22%	12%	0.206
Ever requested technical assistance for a problem	Operator	33%	14%	0.028[a]
In-person visits from external agencies to help with repairs/ maintenance	Committee	20%	7%	0.057[b]
In-person visits from external agencies to help with billing, accounting, etc.	Committee	4%	9%	0.273
Written manuals/material supplied	Committee	30%	18%	0.194
Spare parts provided to village	Committee	9%	5%	0.373
Post-construction training	Household	21%	53%	0.000[c]

Source: Author(s)

Note: We have not presented results for financial support, which was negligible across all villages.

[a] difference is significant at less than .05 level.

[b] difference is significant at less than .1 level.

[c] difference between villages is significant at less than .01 level.

were functioning remarkably well: at the time of our survey a remarkable 95 percent of taps were working in FONCODES villages and 93 percent in SANBASUR villages (Table 2.5). On average, both sets of villages had water available 19–20 hours per day, and more than two thirds of villages had water 24 hours a day.

A majority of schemes in both groups of villages had had major breakdowns in the previous six months. The incidence of breakdowns was notably higher in FONCODES villages, where, according to the system operators, 89 percent of villages had had a major breakdown. Also, if system operators are to be believed, breakdowns took significantly longer to fix in FONCODES villages.

On five out of six household-level measures of problems with the system, SANBASUR projects were outperforming FONCODES projects. For example, households in SANBASUR villages were significantly less likely to have had a leak in the past six months and they were significantly less likely to have had a pipe breakage in the past month. However, SANBASUR villages were significantly more likely than FONCODES villages to have had a pipe breakage in the past six months.

Table 2.5: Physical performance and interruptions

Measure	Data source	FONCODES Average	SANBASUR Average	Anova p-value
Taps working	Operator	95%	93%	0.489
Hours of operation (per day)	Household	18.8	19.9	0.249
Major unplanned interruptions in water supply service for at least one day in past 6 months	Operator	89%	59%	0.129
Number of days to fix major problem	Operator	4.53	1.06	0.047[a]
Major unplanned interruptions in water supply service for at least one day in past 6 months	Leaders	70%	55%	0.117
Number of days to fix major problem	Leaders	2.08	2.58	0.755
Leaks at household level in past month	Household	35%	25%	0.005[b]
Leaks at household level in past 6 months	Household	58%	51%	0.189
Leaks on main pipe in past month	Household	23%	21%	0.464
Leaks on main pipe in past 6 months	Household	50%	43%	0.253
Pipe breakages in past month	Household	28%	20%	0.054[c]
Pipe breakages in past 6 months	Household	24%	39%	0.003[b]

Source: Author(s)

[a] Difference is significant at less than .05 level.

[b] Difference between villages is significant at less than .01 level.

[c] Difference is significant at less than .1 level.

Financial performance

Financial performance was better in SANBASUR villages than in FONCODES villages (Table 2.6), but it must be noted that only 16 percent of SANBASUR village water committees stated that they were collecting enough money to cover major repairs. A significantly higher percentage of households in SANBASUR villages reported that they were currently paying for water, but their responses show they were only paying an average of less than two *soles* (less than US$1) per month.

Consumer satisfaction

On all measures, consumers in SANBASUR villages seemed to be more satisfied than those in FONCODES villages (Table 2.7). The differences are statistically significant in the case of leaders' satisfaction with ongoing maintenance, women's perceptions of water safety, women's satisfaction levels, households' satisfaction with management and operation, and households' overall satisfaction levels. But though they are statistically significant, they are not large.

Perceptions of sustainability

We asked multiple sources about the future sustainability of their water supply systems. Predictably, the longer the time horizon, the fewer respondents thought the system would still be functioning (Table 2.8). This pattern is consistent across surveys.

Table 2.6: Financial performance

Measure	Data source	FONCODES Average	SANBASUR Average	Anova p-value
Amount collected enough to operate system	Committee	46%	49%	0.841
Amount collected enough to make minor repairs	Committee	61%	92%	0.001[a]
Amount collected enough to make major repairs	Committee	7%	16%	0.225
Currently pay for water	Household	69.5%	83.5%	0.037[b]
Amount paid (soles/month)	Household	2.03	1.88	0.794

Source: Author(s)

[a] Difference between villages is significant at less than .01 level.

[b] Difference is significant at less than .05 level.

Table 2.7: Consumer satisfaction

Measure	Data source	FONCODES Average	SANBASUR Average	Anova p-value
Satisfaction with repair service for major breakdowns (range 1–5; 5 is very satisfied)	Leaders	3.5	3.65	0.359
Satisfaction with ongoing maintenance (range 1–5; 5 is very satisfied)	Leaders	3.19	3.65	0.017[a]
Satisfaction with quality of construction (range 1–5; 5 is very satisfied)	Committee	3.98	4.16	0.153
Safety of water (percent groups reporting water is safe)	Women’s group	67%	82%	0.093[b]
Satisfied with water (range 1–5; 5 is very satisfied)	Women’s group	3.22	3.68	0.013[a]
Satisfied with maintenance and repair (range 1–3; 3 is satisfied)	Household	2.8	2.88	0.388
Satisfied with management and operation (range 1–3; 3 is satisfied)	Household	2.54	2.81	0.018[a]
Overall satisfaction level (range 1–3; 3 is satisfied)	Household	2.70	2.86	0.095[b]

Source: Author(s)

[a] Difference is significant at less than .05 level.

[b] Difference is significant at less than .1 level.

Table 2.8: Perceptions of sustainability

Measure	Data source	FONCODES Average	SANBASUR Average	Anova p-value
Belief system will function for next year	Leaders	100%	100%	N/A
Belief system will function for 5 years	Leaders	63%	91%	0.001[a]
Belief system will function for 10 years	Leaders	41%	56%	0.143
Belief system will function for next year	Committee	96%	98%	0.686
Belief system will function for 5 years	Committee	83%	86%	0.682
Belief system will function for 10 years	Committee	52%	59%	0.556
Belief system will function for next year	HH	95.6%	98.3%	0.019[b]
Belief system will function for 5 years	HH	82.4%	88.7%	0.022[b]
Belief system will function for 10 years	HH	68.6%	72%	0.416

Source: Author(s)

[a] Difference between villages is significant at less than .01 level.

[b] Difference is significant at less than .05 level.

2.4 Explaining variation in sustainability: regression analysis

The comparisons above suggest some patterns of difference between the two programs, although some of these patterns are weaker and less significant than we had anticipated. This section analyzes the bivariate relationships among indicators of project sustainability and factors—including post-construction support—that the literature suggests are likely to affect sustainability. While theory suggests more specific relationships, which we shall consider in the multivariate analysis reported in Section 2.5, bivariate analysis allows us to freely examine the strength, direction, and significance of many of the variables that seem crucial for analysis.

For this purpose we incorporated 50 continuous variables into a Pearson's R-correlation matrix that included at least two variables for each of eight categories of factors and four categories of sustainability indicators:

Factors (34 variables)

- Project pre-construction planning (6)
- Project construction contributions (4)
- Project post-construction support (4)
- Project ongoing management (2)
- Project water source (3)
- Village population and density (3)

- Village location in region (3)
- Village socioeconomic status (6)
- Village social capital (3)

Sustainability indicators (16 variables)

- Physical performance of system (7)
- Financial performance—cost recovery (4)
- Consumer satisfaction with water, operation, and administration (3)
- Attitudes concerning future performance (2)

The values used for these variables were derived in three ways. Some came directly from questionnaire responses. Others were constructed, based on responses to questionnaires. For example, the cost-recovery variable denotes whether or not household tariffs in that village are covering operating costs; it is constructed based on responses to the Village Water Committee Survey about financial collections from households as well as about the average cost of operating the water system.

A third group of variables involves multiple dimensions of measurement. For example, "consumer satisfaction" incorporates results from survey questions concerning water attributes, repairs, management, and other issues. In such a case, using one variable to capture all these dimensions of satisfaction is difficult to justify. Hence we used principal-components analysis to generate factor scores for these variables and then estimated models with the factor scores.[14]

Factor-scored variables also assist us in triangulating some responses to questions that were posed to different survey respondent groups. The following example illustrates this technique. Four of our surveys asked questions about community participation during the pre-construction phase. We used confirmatory factor analysis to generate a latent variable (PRECON), with four indicators each representing the responses from one of the surveys, and a fifth indicator, representing household knowledge about planning prior to construction. Factor analysis requires that one variable's coefficient be set to one with a variance of zero, so we placed the fifth variable in this position. The main results appear in Table 2.9. The individual model results suggest that all of the estimates are positive, and all of them except those for household participation are significant between a 5 and 10 percent rejection level. Model-fit statistics indicate that these coefficients jointly differ from the null hypothesis but that the overall model fit is quite limited. The above results are then used to generate factor scores for the latent variable PRECON, which represents the strength of each factor within the score.

Results

Though there were 544 possible significant relationships among the 34 factors and 16 sustainability indicators tested, we found only 104 significant relationships (19 percent of the possible number), using Pearson's R. Even more surprising was the fact that many of the relationships detected were either not hypothesized or ran counter to our expectations. Table 2.10 summarizes the results for each category of sustainability indicators; details are in Appendix 3.1.

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[14] Factor scores attempt to combine multiple measures of a construct into a single measure. They typically generate values that follow a normal distribution, with a mean near zero and a variance depending on the variation among their component elements. Using factor analysis improves the likelihood that a category is reflected by the construct, as opposed to using single variables to represent all categories. Moreover, factor analysis can be superior to using an index, which does not usually reflect the variation contained in each of its components.

Table 2.9: Example: confirmatory factor analysis of community participation *(N=95 villages)*

Indicator	***Type***	***Estimate***	***Significance (z score)***
Household knew system built pre-construction	Categorical	1.00	N/A
Household Survey score	Continuous	0.281	0.51
Leaders' Survey score	Continuous	2.976	1.88[a]
VWC Survey score	Continuous	0.669	1.97[b]
Women's Survey score	Continuous	2.324	1.87[a]

Source: Author(s)

[a] Difference is significant at less than .1 level.

[b] Difference is significant at less than .05 level.

The physical performance of projects is correlated with measures of post-construction support in only 10 percent of the possible cases, rather than the 70 percent that was expected (row 1 of Table 2.10).

For the other three categories of sustainability indicators, the correlations with post-construction support are more frequent. But several of the relationships regarding financial performance are rather surprising. Fewer than half the significant relationships conform to our initial hypotheses. Larger amounts of pre-construction community planning and village contributions during the construction phase, for example, are *negatively* associated with the size of payments that households make for water. And measures of social capital are negatively correlated with

Table 2.10: Summary of bivariate results

Category	***Possible relationships***	***Significant relationships[a]***	***Hypothesized relationships***	***% of hypothesized to total relationships a***
Physical performance	238	24 (10.08%)	17 (70.83%)	7.14%
Financial performance	136	38 (27.94%)	16 (42.1%)	11.76%
Consumer satisfaction	102	27 (26.47%)	22 (81.48%)	21.57%
Future performance	68	15 (22.06%)	9 (60%)	13.26%
Totals	**544**	**104 (19%)**	**64 (61.54%)**	**12.7%**

Source: Author(s)

[a] The percentages in the "Significant relationships" column represent the percentages relative to the total possible relationships, while those in the "Hypothesized relationships" column represent the percentages relative to the significant ones.

Table 2.11: Associations between post-construction support and sustainability

Sustainability category	Sustainability indicator	PCS indicator	Cases	Pearson	Significance
Physical performance	Number of distribution line breaks last 6 months	Factor score	90	0.228	0.031[a]
Physical performance	Average number of operating hours per day	Household visited	96	0.357	0[b]
Financial performance	Percent of households paying for water	Household visited	98	0.279	0.005[b]
Financial performance	Revenue sufficiency score	Household visited	77	0.231	0.04[a]
Consumer satisfaction	Total household satisfaction	Types of water committee support	97	0.299	0[b]
Future performance	5 Year performance (factor score)	Types of water committee support	97	0.26	0.01[a]
Future performance	10 Year performance	Factor score	76	0.366	0.01[a]
Future performance	10 Year performance	Household visited	80	0.345	0[b]
Future performance	10 Year performance	Types of water committee support	80	0.395	0[b]

Source: Author(s)

[a] Difference is significant at less than .05 level.

[b] Difference between villages is significant at less than .01 level.

measures of revenue sufficiency, defined as the ability of villages to meet the costs of operational needs and major and minor repairs through revenue collected from households. By contrast, the relationships between the factors and our measures of consumer satisfaction and attitudes to future performance conform better with our expectations.

Table 2.11 lists the associations between different measures of post-construction support (PCS) and indicators of sustainability. The three PCS measures most closely associated with sustainability are: the totality of post-construction support (technical, visits, financial, spare parts, etc.) that the water committee receives; whether the household has been visited by an external agency; and a total factor score derived for the latent PCS category (this score includes the first two of these PCS measures).

From the bivariate analysis as a whole, the low overall incidence (12.7 percent) of significant and hypothesized relationships suggests that there are fewer than expected significant correlations between (continuous measures of) the presumed determinants of sustainability and our indicators of sustainability.[15] Even the statistically significant relationships are weaker than anticipated in a clear majority of cases. Sustainability outcomes are only weakly affected by pre-construction factors, post-construction support, or other independent variables.

This result is largely attributable to the lack of variation in the indicators of sustainability. The bivariate results do suggest, however, that effective forms of PCS include household visits and various types of support provided to water committees. Other measures of PCS such as system operator training do not emerge as significant indicators of sustainability.

The weak significant relationships among the variables studied affect the specifications and findings of our multivariate models. They suggest that specifications different from those we used would be necessary to achieve both model convergence and plausible estimates of the relevant determinants of sustainability.

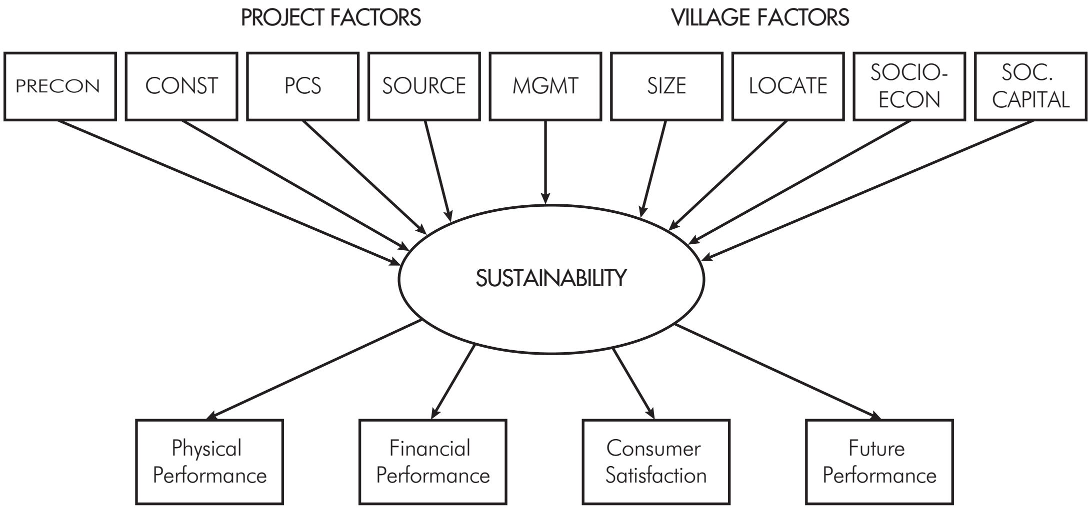
2.5 Explaining variation in sustainability: multivariate analysis

In the multivariate analysis we consider project sustainability from a village-level perspective, using both aggregated household and village-level data. We consider factors such as external post-construction support and management and administrative capacity that have not been analyzed quantitatively in previous studies.

Model overview and justification

Figure 2.1 provides the conceptual model.

Figure 2.1: Operational model of sustainability



Source: Author(s)

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[15] As shown in Appendix 2.3, coefficients are greater than either –0.5 or 0.5 in fewer than 10 percent of all of the significant relationships found.

We hypothesize that the four dimensions of project sustainability (physical performance, financial performance, consumer satisfaction, and expectations about future performance) (S_i) are explained by a vector of project factors (P_i), which includes post-construction support, and a vector of village factors (C_i). A sample equation appears below:

$$S_i = \alpha + P_i X_i + C_i Z_i + e$$

To represent the four dimensions of sustainability we use the following measures (Table 2.12):

- Physical performance
  - Are the household taps, distribution lines, and main lines working?
  - How often does the system break down?

- Financial performance
  - How much do people pay for the water they use?
  - Are household revenues sufficient to cover annual operating and maintenance costs?

- Consumer satisfaction
  - How satisfied are users with water attributes, system operation, and administration/management of the system?
- Attitudes toward future performance
  - Do consumers believe the system will function over a ten-year period?

Table 2.12: Summary of sustainability indicators used in analysis

Category	Indicator	Surveys	Variable type	Data source
Physical performance	Percentage of working taps	Operator	Continuous	Survey response
	Number of breakdowns in last six months (log)	Operator	Continuous	Survey response (transformed as log)
Financial performance	Percentage of households paying for water service	Household	Continuous	Survey response (aggregated)
	Community recovering O&M costs with household contributions	Committee	Binary	Annual revenues from users—(monthly O&M costs*12 months)
Consumer satisfaction	Overall satisfaction	Household	Factor	Village average of factor scores from household responses to ten questions concerning water and management attributes.
Future performance	Ten-year period	Operator, Leaders, Committee	Factor	Multiple survey responses to whether system will function next ten years

Source: Author(s)

To represent the physical- and financial-performance dimensions of sustainability, we use individual variables; we could not generate factor scores due to the weak significant relationships among the variables. Therefore: to represent the physical-performance dimension of sustainability we use data on the percentage of taps working in the village and the number of breakdowns reported in the last six months (transformed into log values for estimation purposes); and to represent financial performance, we use the percentage of households reporting that they paid for water service and a binary variable indicating whether or not the reported annual household collections covered reported operation, maintenance, and repair costs for the previous year.

For both overall consumer satisfaction and attitudes concerning future performance, we generate factor scores as explained in Section 2.4 above. The advantage of using factor analysis in this context is that it models explicitly the creation of categories of our variables. This approach contrasts with that used in prior studies, which made assumptions that the variable(s) truly represented the categorical constructs in the multivariate analysis. The factor score for overall consumer satisfaction derives from responses to questions about satisfaction with the system, construction quality, operation, and management; the factor score model converged successfully and provided statistically significant results that occurred in the same direction of association. The score for attitudes towards future performance combines responses from three surveys as to whether respondents believed their systems would function over a ten-year period; we used binary data (yes/no responses) to generate factor scores, which converged successfully and whose factor loadings appear in the same direction.

As shown in Table 2.13, we assume that the measures of project sustainability can be explained by:

- Project-based factors, including water source characteristics, community involvement during the planning process, demand responsiveness as indicated by household contributions to the project during construction, management capacity of the local administrative water committee, and post-construction support such as training, external visits, financial support, and spare parts.
- Non-project factors, including village size, location, social and economic status, and social capital.

Most of the project-related factors included in the analysis derive from the literature, but a factor that has received less attention in earlier studies is the technical and management capacity of a village. We believe that this capacity enables a village to maintain system performance, generate enough financial support, keep users satisfied with the benefits, and provide assurance that the system will function over time. To that end, our models include explanatory variables representing the number of years of experience of the system operator and of the village water committee. We use a proxy for consumer demand—the mean amount of household labor expended per village—since labor was by far the most common type of community contribution. Other project-related variables include a continuous variable indicating system age, and a dummy variable indicating whether the project was constructed by FONCODES or SANBASUR. The latter variable helps control for unobserved program differences.

Our models also control for community factors. We hypothesize that the size of village population (measured by the number of households) influences sustainability. To measure the community's economic status, we constructed a factor score that combines information from economic indicators such as the average daily wage for non-skilled labor, the percentage of households defined as poor by village leaders, the average number of non-animal assets owned by households, the median household income group, and the average amount of land owned.

Table 2.13: Summary of sustainability factors used in analysis

Category	Indicator	Surveys	Variable type	Measurement type
Project participation	Number of decisions that involved community	Leaders	Index	Sum of 14 possible decisions
Project demand responsiveness	Mean number of labor hours contributed by households	Household	Continuous	Survey response, averaged for each village
Project: technical capacity	Number of years operator working in village	Operator	Continuous	Survey response
Project: managing capacity	Number of years water committee has served in village	Committee	Continuous	Survey response
PCS: households	Percentage of households receiving an external visit in post-construction period	Household	Continuous	Percentage of households per village
PCS: village	Operator or water committee received PCS	Operator, Committee	Binary	Multiple survey responses whether community received any technical or non-technical PCS
Project: program source	FONCODES or SANBASUR program	N/A	Binary	Research design
Project: system age	Number of years new system has operated	Committee	Continuous	Survey response
Community: water source quantity	Length of rainy season (months)	Leaders	Continuous	Survey response
Community: distance to water	Number of kilometers from village to water source	Leaders	Continuous	Survey response
Community: size	Number of households	Leaders	Continuous	Survey response
Community: economic status	Average daily wage, % poverty, median household income, average land ownership, average # assets	Leaders, Household	Factor	Factor score created from set of indicators listed
Community: social capital	Average degree of social capital	Household	Index	Village average of household responses to seven questions

Source: Author(s)

Finally, our social capital measures include a social capital index corresponding to the average level of trust that households reported, as measured by seven questions concerning different groups and situations.

We use ordinary least squares regression to estimate determinants of physical performance (percentage of taps operating and number of breakdowns), the percentage of households paying for water service, and household satisfaction (models 1–3 and 5). We use logistic regression to estimate whether or not a village recovered its operating costs from annual collections and to measure perceptions of ten-year performance (models 4 and 6). Both specifications rely on robust standard errors for hypothesis testing.

Model results

Table 2.14 summarizes the results from model estimation. Controlling for project and non-project determinants of sustainability, they suggest that certain types of post-construction support, notably training and household visits, are linked with household payment for water supply, customer satisfaction, and positive attitudes toward future performance.

Physical performance

The first model indicates that very few factors influence the percentage of taps that are working in Cuzco villages. This finding is not surprising, given that approximately 95 percent of taps were working in all villages at the time of our data collection. Villages that have had more frequent post-construction household visits are more likely to have operational systems—indicating that among villages where many taps are not working, a small group has received few, if any, visits. Communities where operators or village water committee members have been visited are more likely to have experienced breakdowns in the last six months, suggesting that communities with more breakdowns need more help. Stronger determinants of system breakdowns include demand responsiveness and operator experience—leading to fewer breakdowns—and community size—leading to more breakdowns. Other project-related determinants of physical performance vary in strength and significance, yet none appears statistically important beyond a 10 percent rejection level (we use this as our yardstick because the sample is relatively small).

Financial performance

Villages in which a larger share of households reported receiving external visits also contain a larger share of households that pay for water service. The percentage of households paying for service depends on several project-related factors. Communities that had more pre-construction participation and those involved in the SANBASUR program are more likely to have households pay for service and are more capable of reaching operational cost-recovery objectives. Villages with older systems, and villages that relied heavily on contributed labor, are more likely *not* to charge households for water service. Community factors stand out less frequently than project-related factors as important determinants of financial performance. Villages that experience longer rainy seasons more often attain revenue sufficiency. Larger villages pay significantly more often for water service. Other factors play statistically insignificant roles in meeting financial goals.

Consumer satisfaction

Measures of post-construction support for households and for water system officials are strongly associated with overall consumer satisfaction. Other project-related factors affecting consumer satisfaction are rather surprising. Villagers in areas with older systems are more satisfied on average with their water systems than villagers in other areas, yet communities with long-standing

Table 2.14: Coefficients and Z-scores for model results

	Physical – % working taps	**Physical – log # breakdowns**	**Financial – % HHs paid**	**Financial – recover costs**	**Satisfaction- overall**	**Future – function 10 yrs**
Cases	98	98	98	75	98	98
Adjusted R squared	0.12	0.22	0.25	0.24	0.35	0.29
Project participation	–0.0026 (0.85)	–0.003 (0.11)	**2.0275**[a] **(1.81)**	**0.522**[b] **(2.71)**	0.0045 (0.57)	–0.0076 (0.48)
Project: mean labor days	0.0002 (0.25)	**–0.0177**[b] **(2.78)**	**–0.672**[b] **(2.21)**	–0.032 (1.03)	–0.003 (1.36)	0.0014 (0.34)
Project: # years operator served	–0.0041 (0.74)	**–0.0546**[b] **(2.83)**	0.393 (0.41)	0.019 (0.24)	–0.009 (0.12)	0.0018 (0.16)
Project: # years committee served	–0.0014 (0.62)	0.014 (0.54)	**–1.802**[c] **(3.00)**	0.093 (0.97)	**–0.0148**[c] **(3.42)**	**–0.0224**[b] **(1.98)**
Project: SANBASUR	–0.0127 (0.45)	–0.097 (0.46)	**14.754**[a] **(1.77)**	**1.725**[b] **(2.18)**	0.0265 (0.39)	–0.024 (0.20)
Project: system age	0.0033 (0.51)	0.0085 (0.02)	1.116 (0.70)	–0.159 (1.28)	**0.0189**[a] **(1.88)**	–0.0132 (1.05)
PCS: % households visited	**0.0012**[a] **(1.68)**	0.0014 (0.37)	**0.3765**[c] (3.17)	0.0037 (0.17)	0.003b (2.62)	**0.0054**[b] **(2.77)**

Table 2.14: Coefficients and Z-scores for model results (*continued*)

	Physical – % working taps	***Physical – log # breakdowns***	***Financial – % HHs paid***	***Financial – recover costs***	***Satisfaction- overall***	***Future – function 10 yrs***
PCS: committee or operators received	–0.0268	**0.3272**[a]	3.705	1.0136	**0.0686**[a]	**0.2754**[b]
	(0.82)	**(1.69)**	(0.52)	(1.49)	**(1.64)**	**(2.76)**
Community: km to water source	–0.0041	0.0032	–0.6	–0.013	**–0.004**[a]	0.0047
	(1.53)	(0.28)	(1.57)	(0.28)	**(1.64)**	(0.92)
Community: # households	–0.000	**0.002**[b]	**0.077**[b]	0.0024	0.0002	–0.0005
	(0.03)	**(2.22)**	**(2.45)**	(0.62)	(0.87)	(1.05)
Community: economic status	–0.0053	–0.1133	–4.153	0.054	–0.0375	–0.047
	(0.62)	(1.61)	(1.54)	(0.21)	(1.36)	(1.36)
Community: social capital	–0.0105	0.0529	–1.371	0.261	**0.0264**[b]	0.0356
	(1.24)	(1.31)	(0.78)	(1.49)	**(2.33)**	(1.50)

Source: Author(s)

[a] Difference is significant at less than .1 level.

[b] Difference is significant at less than .05 level.

[c] Difference between villages is significant at less than .01 level.

water committees are less likely to voice satisfaction with their water and management services. Community factors resemble our hypotheses more closely: villages with high levels of consumer satisfaction tend to be those with higher median social capital and longer rainy seasons, while villages farther away from their water sources are more dissatisfied.

Perceptions of sustainability

Some three out of four villagers thought that their system would still be functioning in five years' time. According to our model results, this perception is not influenced by post-construction support. However, respondents who live in villages receiving post-construction support are more likely to believe that their system will function over a *ten*-year period. The only other factor related to villagers' confidence about their system's future performance is the length of time that water committees have served; surprisingly, the longer the committee has served, the less confident the villagers are about the sustainability of the system.

To sum up, our models are clearly not perfect representations of the sustainability of water projects in Cuzco villages. The fit of each model, as indicated by R-squared values, is quite limited. Some factors, such as economic status, are unimportant across any individual measure of sustainability. Other proxies (mean contributed labor, number of years a water committee has existed) yield counterintuitive results. Nevertheless, the models do indicate that some elements of post-construction support are associated with improving elements of sustainability.

2.6 Discussion and Conclusions

We studied villages in the Cuzco Department of Peru that received a water project through either SANBASUR or FONCODES. We tried to control for such differences among the villages in order to isolate the effects of post-construction support on the sustainability of water projects.

Our study encountered some difficulties that limited our ability to make inferences and generalize our findings. In particular, many of the village water systems were performing better than expected, particularly in terms of physical measures such as the high percentages of taps that worked in villages and the relatively short lengths of time needed to make many repairs. This is good news for many villages, but the lack of variation among some of our dependent variables made it difficult to assess the importance of PCS.

As expected, SANBASUR villages generally received more post-construction support than FONCODES villages. System operators in SANBASUR villages received more technical support and training and a larger percentage of households in SANBASUR villages received training after construction. This said, SANBASUR villages did not receive extremely high levels of post-construction support, and FONCODES villages received more PCS than we had expected.

Ultimately, both the SANBASUR and FONCODES systems provided for demand-driven PCS. SANBASUR worked with and trained local municipalities and interlocutor NGOs to provide post-construction support, but SANBASUR villages had to request the support themselves. Additionally, because the SANBASUR villages were much more remote than FONCODES villages, they presumably had a harder time *demanding* PCS. Thus we observed lower levels of PCS in SANBASUR villages than we had expected. In the FONCODES program, nothing inherently prevented villages from also requesting support (in some cases probably from the same municipal agencies that SANBASUR had trained). There is also some evidence that FONCODES villages had demanded post-construction support in the form of spare parts and in-person visits from external agencies.

The facilities in both SANBASUR and FONCODES projects were generally functioning well, with residents largely using private taps to obtain their water. SANBASUR villages had slightly higher levels of consumer satisfaction than FONCODES villages. SANBASUR villages had also achieved better financial performance than FONCODES villages—though only 16 percent of SANBASUR water committees reported that they were collecting enough money to cover major repairs. SANBASUR villagers also perceived that their systems would remain functional longer than did FONCODES villagers.

An examination of bivariate relationships shows that indicators of sustainability are only weakly affected by pre-construction factors, post-construction support, or other independent variables. This result is largely attributable to the lack of variation in the dependent variables. The bivariate analysis does suggest, however, that effective forms of PCS include household visits and types of support provided to water committees. (Other measures of PCS such as system operator training do not emerge as significant indicators of sustainability.)

The results of our multivariate analysis show that village water supply systems in Cuzco are likely to be functioning whether or not they receive PCS. A surprising number of sampled communities had been delivering water on a consistent basis over moderate to even longer periods (10–15 years) without PCS. Many systems broke down, yet communities had often been able to mobilize their resources to get the systems running again. However, it is also clear that a smaller set of communities, whose water systems were not functioning as well, were demanding post-construction support more frequently. This suggests that post-construction assistance would prove most beneficial to communities that are struggling with intermittent service, limited coverage, and frequent breakdowns.

Post-construction assistance is having some impact on the implementation of "user pays" principles of system financing: villages in which more households had received visits from external agencies were more likely to have users paying for water service. These findings are interesting because the reported purpose of many of these visits was not to coax households to pay for service; typically they featured hygiene education and "how-to" training for the use of household yard taps. Yet the results suggest that households are more likely to value their water supply service if they are visited for these related purposes after construction. Village-level PCS had neither reduced the incidence of non-payment nor encouraged cost recovery. Only a few villages had received direct external financial or non-technical financial management assistance. Given that households were paying less than US$1 per month, on average, for service, it is not surprising if PCS had little influence on community financial practices. There appears to be a great deal of room for improvement in financial management at the village level.

Households in communities that had received both village and household-level forms of PCS were more satisfied than households in communities that did not receive both forms of assistance. While this is an important initial finding, we believe that more specific models, incorporating individual household factors, may improve the ability to predict individual user satisfaction among specific sets of attributes.

Our models failed to generate meaningful estimates of the effect of PCS on village attitudes towards whether the systems would be functioning in five years' time. This may reflect the broad confidence communities had in their systems; about 75 percent of respondents thought their systems would still be functioning in five years' time. Over a ten-year horizon, however, those villages where water committees or operators were receiving PCS were more likely to be confident that their system would keep running.

This relationship between PCS and optimism about sustainability can perhaps be attributed to community realizations that a wider support network for the water system exists, going beyond the system operator and water committee. This realization is valuable, but it could have perverse financial implications if households think that this wider support network will step in and make any major repairs or expansions to the system when necessary.[16]

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[16] Indeed, any form of PCS may encourage such a misperception, which could perhaps be modified by some type of education about the exact nature of support available.

APPENDIX 2.1: PROTOCOL USED FOR SAMPLING HOUSEHOLDS

This appendix is an excerpt from the field manual developed for the study.

There are different methods of selecting households for the household surveys in each community. Each technique depends upon the level of information available in each village. The following outlines the protocol that field coordinators should use to determine how to sample households at the village level. These options are ordered from best-case to worst-case scenarios. Field coordinators must select the option that best fits the amount of information available at the village level.

First steps

Upon arrival in a village, the field coordinator will seek out village leaders and ask to see a list of households in the village. Some villages will have a list of households either from census information or from village resources. If a village does have a complete list of households no more than two years old, field coordinators will use the Option 1 strategy for household selection, described below.

If a village does not have a complete, updated list of households, the field coordinator will ask village leaders to work with him/her in devising a sample map of households. For some SANBASUR projects, a preliminary map from the initial diagnostic (pre-project) study may already be available; field coordinators should check their documents to see if they have this map in hand. The field coordinator will work with the village leaders to sketch this map. In particular, this map should identify: (1) the location of the main pipeline within village limits; and (2) higher-wealth and lower-wealth residential areas, providing a rough estimate of their relative sizes. Upon completion of this map, the field coordinator will use the Option 2 strategy for household selection, described below.

Field coordinators may be unable to sketch a residential map of the area, possibly because they cannot find village leaders or others in the village who have the necessary information to sketch an informal map. This represents a worst-case scenario, and field coordinators should do their best to obtain either a list of households or a village map. In this case, field coordinators should proceed to the Option 3 strategy for household selection, described below.

Option 1: Complete List of Households Available in the Village

Upon obtaining a complete list of households from the village, field coordinators will use simple random sampling to draw 40 households from the list. The simplest method for doing this is to write down numbers from one to the last number of households on small scrap sheets of paper, place them in a hat, bowl, etc., and then randomly select 40 numbers. Field coordinators with computers that have random-number generating programs may use these programs as an alternative to this strategy.

These numbers will represent your sample of households. Field coordinators will collect address or location information for each household, and work with village leaders or registry keepers to determine what areas of the village these households are located in. Field coordinators will divide these into four proportional areas of different sizes, then send enumerators to each area to conduct household interviews during the day. Field coordinators will divide areas and assign households to each selected enumerator based on the following formula:

Enumerator	***# Interviews Required***	***# Potential Households Assigned***
1	3	5
2	6	10
3	6	10
4	8	15

Enumerators will visit each of the assigned households until they have completed the requisite number of interviews. If they have visited all of their households but have not completed their interviews, they should revisit the houses to check if a household member has returned. Once an enumerator has completed his/her interviews, he can return to a site designated by the field coordinator and begin checking surveys. If an enumerator cannot locate the requisite number of interviewees in his/her area, the field coordinator can instruct him to assist another enumerator.

Option 2: List of Households Unavailable, Detailed Map of Village Available

Once the field coordinator has produced a detailed sketch map identifying the main water pipeline, residential concentrations, and spatial areas of wealth in the village, the field coordinator will attempt to divide the village into clusters. These clusters will roughly typify the following categories: (1) higher-wealth area, near the main pipeline; (2) higher-wealth area, further from main pipeline; (3) lower-wealth area, near the main pipeline; (4) lower-wealth area, further from main pipeline.

It may be difficult to define these clusters. Some villages may feature little difference in wealth or distance from the main pipeline. Households in other villages may be more dispersed. The objective, however, is to sample households from areas of relatively higher and lower wealth and areas that are closer to and farther away from the main distribution line. If field coordinators determine, for instance, that the differences in wealth and distance from the main pipeline are small, then field coordinators should select clusters that represent the diversity of wealth and distance in the village.

Once these clusters have been identified, the field coordinator will place the clusters into the following groups: Group 1 will contain households in high-wealth, close-distance areas and low-wealth, close distance areas. Group 2 will contain households located in high-wealth, further-distance areas and households located in low-wealth, further-distance areas.

Field coordinators will send enumerators #1 and #4 to work in the two groups near the main pipeline and send enumerators #2 and #3 to work in the two groups further from the main pipeline. Enumerators will begin at an intersection in the group closest to the center of the village, then walk through the cluster and interview households encountered, based on the following formula with respect to village populations:

- Populations 400–599: every 2nd household
- Populations 600–799: every 3rd household
- Populations 800–999: every 4th household
- Populations 1,000–1,199: every 5th household
- Populations 1,200–1,399: every 6th household

- Populations 1,400-,1599: every 7th household
- Populations 1,600–1,799: every 8th household
- Populations 1,800–1,999: every 9th household

Enumerators who are working through the day who have completed their walks through the clusters but have not completed their requisite number of interviews should return to the beginning household. If no one was home at this household during the first round, the enumerator should check to see if someone has since arrived to interview. If no one is home yet, the enumerator should then go to the household next door (e.g. on the right). The enumerator will follow the same procedure for every *n*th household (i.e. the enumerator will go to the 5th household, check if they have been interviewed and knock if they have not, then proceed to the household next door). Once an enumerator has completed his/her interviews, he can return to a site designated by the field coordinator and begin checking surveys.

If an enumerator cannot locate interviewees in his/her area, the field coordinator can advise him to assist another enumerator. Enumerators who assist another enumerator in a different cluster must check with that person to determine where they are in the rotation, and operate using the same formula described above.

Option 3: List of Households Unavailable, Detailed Social Map Unavailable

If field coordinators are unable to obtain a list of households or sketch a detailed social map, field coordinators must resort to what is called systematic cluster sampling with random starting points. In this method, field coordinators will divide the village into four geographic areas (these are not based on wealth or distance since these measures are presumably unavailable), based on a walk through the village. Field coordinators will guess how many people live in each area, and then send enumerators to each geographic area in proportion to the assigned number of interviews they need to complete.

From the household closest to the village center, the enumerator will then proceed to count all of the houses in his/her geographic area and number them on a map that they will sketch. Afterwards, the enumerator will select one number at random from the list and begin interviews at that household. Field coordinators will instruct enumerators to use the same strategies for interviewing subsequent numbered households as that described in Option 2.

Sampling Female and Male Respondents

Enumerators should try to achieve some balance of female and male respondents. It is likely that, in early interviews during the day, there will be more female respondents at home. Enumerators who conduct interviews later in the day should make a concerted effort to find male subjects. At least two of the interviews conducted by each enumerator in the afternoon should be men (or women, if the morning's enumerators find that they have a very high proportion of men in their sample). Field coordinators should work with enumerators to help ensure gender representation.

At the End of the Day

Field coordinators will explain in detail the procedures they used for sampling households in each village and justify their reasons for doing so in the Field Note. They will also report any difficulties they or their enumerators encountered along the way, and discuss what measures they took in response. This information is extremely important for the study team because it allows us to cross-check the collected household data with the protocols used by field coordinators and enumerators to determine the quality of the information obtained from households in each village.

APPENDIX 2.2: GENDER DIFFERENCES

To examine whether consumer satisfaction with water systems differed between women and men, we reviewed the raw responses (ungrouped by village) to twelve questions in the household survey. The table below details some of these responses. Nearly half showed significant differences. Overall, female respondents had a better impression of the systems than male respondents.

Generally, women had not taken an active role in water committee administration. The 89 water committees responding to the survey had five members on average, with a minimum of one and maximum of ten. But among 85 of the committees, the mean number of women was only 0.55, with a minimum of zero and maximum of three.

Measure	Male responses	Female responses	Chi-square dif.
Satisfaction with maintenance & repairs	67.8% satisfied	73.78% satisfied	0.006
System will function next 5 years	76.1% yes	75.3% yes	0.139
System will function next 10 years	50.4% yes	45.9% yes	0.007
Quality of construction	65.7% good or excellent	72.2% good or excellent	0.004
Satisfaction with management & operations	59.5% satisfied	63.3% satisfied	0.008
Water pressure during dry season	45.8% good or excellent	46.2% good or excellent	0.982
Taste of water at tap	80% no flavor	81.5% no flavor	0.812
Color of water at tap	97.4% no color	97.5% no color	0.689
Odor of water at tap	85.4% no smell	88.3% no smell	0.226
Water safe to drink	73.5% yes	71.3% yes	0.504
Water available when it's supposed to be	68.6% yes	71.8% yes	0.266
Water meets household needs	70.4% yes	74.2% yes	0.046

Source: Author(s)
Note: Overall, there were 1,360 male respondents and 1,089 female respondents (a 55/45 split) in the sample.

APPENDIX 2.3: SIGNIFICANT BIVARIATE RELATIONSHIPS AMONG INDIVIDUAL VARIABLES AND FACTOR SCORES

Dep Var Type	Dep. Variable	Indep. Type	Indep. Variable	Cases	Pearson	Sign	Expected
Financial	Monthly fee for water	Pre-Construction	Factor score	67	–0.654	0	No
Financial	Monthly fee for water	Social Capital	Factor score	68	–0.647	0	No
Financial	Monthly fee for water	Pre-Construction	Community Involvement	69	–0.55	0	No
Financial	Monthly fee for water	Pre-Construction	VWC index	67	–0.522	0	No
Financial	Monthly fee for water	Social Capital	HH index	69	–0.509	0	No
Financial	Monthly fee for water	Pre-Construction	Factor score	51	–0.491	0	No
Financial	Total revenue sufficiency	Economic status	% poverty	72	–0.455	0	No
Financial	Monthly fee for water	Construction	% HHs contributing	69	–0.444	0	No
Financial	Monthly fee for water	Construction	HH amt contributed	69	–0.416	0	No
Financial	Monthly fee for water	Construction	HH labor contributed	51	–0.401	0.004	No
Financial	Monthly fee for water	Pre-Construction	Community discussions	69	–0.366	0.002	No
Financial	Monthly fee for water	Pre-Construction	Women's participation	69	–0.343	0.004	No
Financial	Monthly fee for water	Economic status	# animals	69	–0.339	0.004	No
Financial	Monthly fee for water	Village	Distance-road	58	–0.337	0.01	Yes
Financial	Monthly fee for water	Pre-Construction	VWC index	95	–0.33	0.001	No
Financial	Monthly fee for water	Pre-Construction	Factor score	95	–0.321	0.002	No
Financial	Monthly fee for water	Construction	% HHs contributing	98	–0.318	0.001	No
Financial	Monthly fee for water	Social Capital	Factor score	97	–0.287	0.004	No
Financial	Total revenue sufficiency	Pre-Construction	Women's participation	77	–0.286	0.009	No

(continued)

Dep Var Type	**Dep. Variable**	**Indep. Type**	**Indep. Variable**	**Cases**	**Pearson**	**Sign**	**Expected**
Financial	Monthly fee for water	Social Capital	Leaders index	68	–0.273	0.024	No
Financial	Monthly fee for water	Economic status	% poverty	98	–0.25	0.016	Yes
Financial	Monthly fee for water	Social Capital	HH index	98	–0.248	0.014	No
Financial	Total revenue sufficiency	Pre-Construction	Community planning	77	–0.231	0.043	No
Financial	% HHs paying for water	Management	VWC # Yrs.	80	–0.224	0.046	No
Financial	Total revenue sufficiency	Social Capital	Leaders index	76	0.004	0.323	Yes
Financial	Total revenue sufficiency	Social Capital	HH index	77	0.037	0.238	Yes
Financial	Monthly fee for water	Social status	Factor score	98	0.208	0.039	Yes
Financial	Total revenue sufficiency	Post-Construction	HH visits	77	0.231	0.04	Yes
Financial	Monthly fee for water	Economic status	# assets	98	0.238	0.018	Yes
Financial	Total revenue sufficiency	Source	# months rainy season	71	0.244	0.04	Yes
Financial	% HHs paying for water	Social Capital	Leaders index	97	0.25	0.014	Yes
Financial	% HHs paying for water	Post-Construction	HH visits	98	0.279	0.005	Yes
Financial	Monthly fee for water	Source	# months rainy season	63	0.299	0.017	Yes
Financial	Monthly fee for water	Economic status	Average day wage	67	0.509	0	Yes
Financial	Monthly fee for water	Economic status	Factor score	66	0.516	0	Yes
Financial	Monthly fee for water	Economic status	# assets	69	0.526	0	Yes
Financial	Monthly fee for water	Economic status	Factor score	44	0.602	0	Yes
Financial	Monthly fee for water	Social status	Factor score	69	0.65	0	Yes
Future Operation	Function in 5 Years	Economic status	Factor score	66	–0.344	0.005	No

(*continued*)

Dep Var Type	**Dep. Variable**	**Indep. Type**	**Indep. Variable**	**Cases**	**Pearson**	**Sign**	**Expected**
Future Operation	Function in 5 Years	Pre-Construction	HH index	97	–0.342	0.001	No
Future Operation	Function in 5 Years	Social status	Factor score	97	–0.28	0.006	No
Future Operation	Function in 10 Years	Economic status	Factor score	55	–0.267	0.049	No
Future Operation	Function in 10 Years	Management	VWC # Yrs.	66	–0.243	0.049	No
Future Operation	Function in 10 Years	Pre-Construction	HH index	80	–0.23	0.04	No
Future Operation	Function in 5 Years	Social Capital	Factor score	97	0.253	0.012	Yes
Future Operation	Function in 5 Years	Post-Construction	VWC support	97	0.26	0.01	Yes
Future Operation	Function in 10 Years	Village	Distance –river	80	0.261	0.02	Yes
Future Operation	Function in 10 Years	Construction	Factor score	64	0.271	0.03	Yes
Future Operation	Function in 10 Years	Construction	Household contribution amount	64	0.286	0.022	Yes
Future Operation	Function in 5 Years	Social Capital	Leaders index	97	0.335	0.001	Yes
Future Operation	Function in 10 Years	Post-Construction	HH visits	80	0.345	0.002	Yes
Future Operation	Function in 10 Years	Post-Construction	Factor score	76	0.366	0.01	Yes
Future Operation	Function in 10 Years	Post-Construction	VWC support	80	0.395	0	Yes
Physical	# breakdowns last 6 months	Economic status	Avg. day wage	95	–0.337	0.001	Yes
Physical	# dist. Line breaks last 6 months	Village	Households	91	–0.277	0.008	Yes
Physical	# main Line breaks last 6 months	Construction	Household contribution amount	95	–0.269	0.008	Yes
Physical	# main line breaks last 6 months	Economic status	Avg. day wage	92	–0.266	0.01	Yes

(continued)

Dep Var Type	Dep. Variable	Indep. Type	Indep. Variable	Cases	Pearson	Sign	Expected
Physical	# main line breaks last 6 months	Source	Factor score	78	–0.251	0.027	Yes
Physical	# breakdowns last 6 months	Management	Op # yrs exp	97	–0.248	0.014	Yes
Physical	# dist. Line breaks last 6 months	Construction	Household contribution amount	97	–0.228	0.025	Yes
Physical	# project taps working	Economic status	# animals	92	–0.225	0.031	No
Physical	# breakdowns last 6 months	Source	Factor score	78	–0.221	0.048	Yes
Physical	# times tap broke last 6 months	Construction	% HHs contributing	97	–0.201	0.049	Yes
Physical	# hours per day operational	Pre-Construction	Leaders index	96	0.22	0.031	Yes
Physical	# dist. Line breaks last 6 months	Post-Construction	Factor score	90	0.228	0.031	No
Physical	# dist. Line breaks last 6 months	Post-Construction	Factor score	90	0.228	0.031	No
Physical	# main line breaks last 6 months	Village	Distance -river	93	0.237	0.022	Yes
Physical	# main Line breaks last 6 months	Construction	% HHs contr.	95	0.245	0.017	No
Physical	# dist. Line breaks last 6 months	Economic status	% poverty	92	0.268	0.01	No
Physical	# main line breaks last 6 months	Economic status	# animals	95	0.276	0.007	No
Physical	# main line breaks last 6 months	Village	Distance -river	82	0.303	0.006	Yes
Physical	# hours per day operational	Pre-Construction	# decisions	96	0.31	0	Yes

(continued)

Dep Var Type	**Dep. Variable**	**Indep. Type**	**Indep. Variable**	**Cases**	**Pearson**	**Sign**	**Expected**
Physical	# main line breaks last 6 months	Village	Distance-road	82	0.33	0.002	Yes
Physical	# hours per day operational	Post-Construction	# HHs visited	96	0.357	0	Yes
Physical	# hours per day operational	Source	Factor score	79	0.414	0	Yes
Physical	# hours per day operational	Source	Factor score	79	0.414	0	Yes
Physical	# main line breaks last 6 months	Pre-Construction	HH index	95	0.488	0	No
Satisfaction	Satisfaction from household	Management	VWC # Yrs.	79	–0.327	0.003	No
Satisfaction	Satisfaction w/ water	Village	Density	74	–0.311	0.007	Yes
Satisfaction	Satisfaction w/ administration	Economic status	Factor score	66	–0.279	0.023	No
Satisfaction	Satisfaction w/ water	Village	Households	76	–0.276	0.016	Yes
Satisfaction	Satisfaction from household	Economic status	Factor score	65	–0.252	0.043	No
Satisfaction	Satisfaction w/ administration	Village	Density	91	–0.249	0.017	Yes
Satisfaction	Satisfaction from household	Social status	Factor score	97	–0.23	0.024	No
Satisfaction	Satisfaction w/ administration	Source	Factor score	81	0.223	0.045	Yes
Satisfaction	Satisfaction w/ water	Economic status	# animals	80	0.228	0.042	Yes
Satisfaction	Satisfaction w/ administration	Pre-Construction	Women's participation	94	0.23	0.023	Yes
Satisfaction	Satisfaction w/ administration	Social Capital	Factor score	97	0.232	0.022	Yes
Satisfaction	Satisfaction from household	Economic status	# animals	97	0.2323	0.022	Yes
Satisfaction	Satisfaction from household	Construction	Household contribution amount	73	0.236	0.044	Yes

(continued)

Dep Var Type	**Dep. Variable**	**Indep. Type**	**Indep. Variable**	**Cases**	**Pearson**	**Sign**	**Expected**
Satisfaction	Satisfaction from household	Social Capital	HH index	97	0.257	0.011	Yes
Satisfaction	Satisfaction w/ administration	Social Capital	HH index	97	0.257	0.011	Yes
Satisfaction	Satisfaction from household	Social Capital	Factor score	96	0.271	0.008	Yes
Satisfaction	Satisfaction w/ administration	Pre-Construction	Community planning	94	0.282	0.006	Yes
Satisfaction	Satisfaction from household	Post-Construction	# HHs visited	97	0.299	0.003	Yes
Satisfaction	Satisfaction w/ administration	Pre-Construction	Community Involvement	97	0.321	0.001	Yes
Satisfaction	Satisfaction w/ administration	Pre-Construction	# decisions	97	0.344	0.001	Yes
Satisfaction	Satisfaction w/ water	Pre-Construction	Factor score	78	0.346	0.002	Yes
Satisfaction	Satisfaction w/ administration	Pre-Construction	Factor score	94	0.358	0	Yes
Satisfaction	Satisfaction w/ administration	Pre-Construction	Factor score	94	0.358	0	Yes
Satisfaction	Satisfaction w/ water	Source	Factor score	66	0.361	0.003	Yes
Satisfaction	Satisfaction w/ water	Pre-Construction	Community Planning	78	0.369	0.001	Yes
Satisfaction	Satisfaction w/ administration	Source	Source index	84	0.38	0	Yes
Satisfaction	Satisfaction w/ water	Source	Source index	69	0.453	0	Yes

Source: Author(s)

CHAPTER 3:
SUSTAINING THE BENEFITS OF RURAL WATER SUPPLY INVESTMENTS: EXPERIENCE IN COCHABAMBA AND CHUQUISACA, BOLIVIA[17]

Summary

This study explores the contribution of post-construction support (PCS) to the sustainability of rural water supply systems in two departments of Bolivia's Central Highlands. All the 99 communities studied had taken part in PROSABAR (*Proyecto de Saneamiento Básico Rural*), a rural water supply project that took a demand-responsive, community-management approach. Using regression and matched-pair statistical analyses, we assess the extent to which post-construction support is positively associated with system functioning and user satisfaction, after controlling for observed community and technology characteristics and for features of the project planning process. Overall, the research shows that water systems in the 99 communities studied were performing unexpectedly well. Communities that received management-oriented PCS visits from external agencies, as well as those whose system operators attended training workshops in the post-construction period, had better performing systems than communities that received no such support. Engineering-oriented PCS had no measurable impact on system functioning or user satisfaction.

3.1 Introduction

By 2002, two thirds of Bolivia's rural population had access to improved water supply services, according to the Joint Monitoring Program of the World Health Organization and UNICEF.[18] This rate of access was considerably better than a decade earlier, when the Bolivian national census had found that only 24 percent of rural households had access to safe water (Sara et al. 1996). One of the rural water projects that the Bolivian Government implemented during the 1990s was PROSABAR (*Proyecto de Saneamiento Básico Rural*), an outgrowth of a World Bank-supported pilot project implemented in the department of Potosi. This study is based on follow-up visits to communities in two departments of Bolivia's central highlands, Chuquisaca and Cochabamba, who participated in this project. The communities featured are located in 18 rural municipalities that lie in the *tierra fria* climate zone (1,800 to 3,000 meters). This region has distinct rainy and dry seasons, with most of the annual precipitation falling between November and March; annual rainfall varies from 30–69 centimeters.

PROSABAR

PROSABAR was launched in 1993, and provided improved water supplies to more than 330,000 citizens in 762 communities before it closed in 2001. The project emphasized a "demand-responsive" approach to technology selection and implementation, in which community members would have primary control over key project decisions and would also assume primary responsibility for the long-term operation and maintenance of the installed water systems (Sara et al. 1997).

Many elements of PROSABAR were shaped by concerns for sustainability. The project used lower-cost technologies than its predecessors in Bolivia, and required community members to make cash

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[17] This chapter was written by Jennifer Davis, Heather Lukacs, Marc Jeuland, Alfonso Alvestegui, Betty Soto, Gloria Lizárraga, Alex Bakalian, and Wendy Wakeman. We are grateful to Rob Chase, Kristin Komives, Vijayendra Rao, Robert Roche, Jennifer Sara, Meike van Ginneken, and Dale Whittington for helpful comments. We also extend sincere thanks to the members of our field team for their hard work and dedication to this study, and to the sample communities for sharing their time and experiences.

[18] World Health Organization (WHO) and United Nations Children's Fund (UNICEF) *Joint Monitoring Program (JMP) for Water Supply and Sanitation database.* Available at JMP website <*http://www.wssinfo.org/en/welcome.html*>.

and non-cash contributions toward the up-front costs of the new systems.[19] Communities were also allowed to select the technology and level of service that best matched their preferences, willingness and ability to pay for ongoing maintenance, as well as water source quality and yield.

Community management approach

PROSABAR largely embraced the notion of community management of water supply infrastructure and of capacity building for this purpose within participating communities. Each community participating in the project was required to form a water and sanitation committee (*Comité de Agua y Saneamiento*, or CAPYS) that would be responsible for managing the installed system. Each committee was required to identify at least one local person who would undergo training and assume responsibility for operation and maintenance (Sara et al. 1997).

Post-construction support

In 1999, roughly five years into the implementation of PROSABAR, efforts were made to establish a support system for the post-construction phase. The original intent was that municipal government would provide PCS or organize its provision through third party. As designed, the system had two elements: a network for sharing information and a set of technical units that were established at the municipal level. The Water and Sanitation Network *(Red de Saneamiento Básico)* was established to encourage the exchange of information and experiences among the CAPYS, municipalities, departmental administrations (*prefecturas*), and the Vice Ministry for Basic Services; within each of Bolivia's nine departments, a water and sanitation unit *(Unidad de Saneamiento Básico y Vivienda*, or UNASBVIS) was expected to serve as the focal point for information collection and dissemination. In each municipal capital, a municipal technical unit *(Unidad Técnica Municipal,* or UTIM*)* was established and given responsibility to assess the need for—and organize—capacity building in PROSABAR communities, as well as to provide regular technical backstopping to CAPYS and system operators. The *técnicos* in the UTIMs were provided with training by the departmental-level UNASBVIS and with motorcycles so they could periodically visit the communities within their jurisdiction.

The Network and the UTIMs operated in five departments for roughly two years. In 2001, the Vice Ministry of Basic Services provided funding that amounted to 70 percent of the total cost of PCS support, with the expectation that municipalities would subsequently assume responsibility for financing PCS. In practice, however, since 2001 PCS has been provided on an ad hoc basis, inconsistently across municipalities and communities.[20] At the same time, several non-governmental organizations (NGOs) such as Plan International and CARE also began to offer post-construction support within the PROSABAR communities located in their operational jurisdictions. Circuit riders visiting communities focused their attention on the water committees (CAPYS), providing support and guidance related to tariff design, accounting and other administrative issues.

Outline of study

Section 3.2 of this chapter describes the sample selection and data gathering. Descriptive findings on the sustainability of water systems in the sampled communities are presented in Section 3.3. Discussing the reasons for variations in sustainability, Section 3.4 reports on the findings

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[19] Under the Yacupaj pilot project, communities contributed more than half the value of the initial costs in cash and kind. This percentage was lower in the national PROSABAR project, at between 20–25 percent.

[20] Indeed, a 2002 evaluation of PROSABAR concluded: "The end of construction [typically] coincides with the end of government involvement in rural water supply and sanitation… There is little evidence of functioning municipal UTIMs (*unidades tecnicas internas municipales*) that could provide technical and operational assistance to the local communities in the operations and maintenance of their water supply and sanitation systems" (OED 2002).

of regression analysis, and Section 3.5 reports on the results of matched-pair analysis, which investigates how sustainability is affected by various types of post-construction support. Section 3.6 concludes.

3.2 Sample selection and data gathering

During September and October 2005, six field teams visited 99 communities in the *departamentos* of Cochabamba and Chuquisaca that had received piped water systems through PROSABAR before the year 2000. In each community, the teams interviewed system operators and held focus group discussions with water committee members and with female community members. In addition, more than 2,000 household interviews were completed across the 99 communities. Data were collected in participants' preferred language—either Castellano or Quechua.

Within each community, all water committee members, as well as the water system operator(s), were sought out for interviews. Participants in each women's focus group were selected purposively, with the help of a local intermediary, with the goal of representing the range of socioeconomic and demographic characteristics extant within a given community. Respondents in the household sample were selected using a stratified sampling of housing units from a community map that was drawn by the field supervisor with assistance from community leaders. The map was divided into geographic strata based upon the water distribution network, elevation, and housing density, and 25 households were then selected by random sampling, with the fraction of households drawn from each stratum being roughly proportional to the community as a whole. Although the field teams did not intentionally stratify respondents by gender, across the entire sample of 2,365 households 50 percent of the individuals interviewed were male and 48 percent were female (both male and female heads of household participated in 2 percent of the interviews).

In addition, in each community a licensed engineer, accompanied by the water system operator, carried out visual inspection of the distribution network, water storage tanks, and, where possible, the water source and transmission lines. In each community the engineer completed a standardized evaluation form that recorded information about the physical condition of these water system assets. No water quality sampling was undertaken as part of this assessment.

The communities included in the study sample were selected using both secondary data and in-person visits to the municipal capitals of Cochabamba and Chuquisaca. All the sample communities had participated in PROSABAR and received improved water supply services at some point during the period 1993–2000. Each had a population between 100 and 2,000 residents. Within each of the two departments, we initially tried to cover about 25 communities that had received some form of systematic post-construction support (PCS) and another 25 that had not. In practice we found it difficult to distinguish "treatment" from "control" communities, however, because many of the municipal records regarding the provision of PCS turned out to be incorrect. When this was discovered, the field teams reclassified communities into members of the "treatment" or "control" group based on interviews, reports, and records related to PCS in each community.

Another challenge for our analysis stems from the fact that some communities in our sample received PCS in an unsolicited manner (i.e., at the decision of the provider), while others solicited it (Table 3.1), typically through personal visits to municipal or NGO offices. From an analytical perspective, investigating the effects of unsolicited PCS is preferable because it allows for test

Table 3.1: Type and frequency of post-construction support reported by CAPYS members[a]

	% of communities that received indicated type of PCS	**Among communities receiving PCS, % that solicited it**	**Among communities receiving PCS, median, mean number of times support was provided since construction**
Visits from external organization(s) to assist with maintenance or repairs	22%	29%	Median: 2 Mean: 5 SD: 8.1
Visits from external organization(s) to assist with accounting, tariffs, etc.	13%	38%	Median: 2 Mean: 2 SD: 0.9
Provision of technical training to system operator	41%	10%	Median: 2 Mean: 3 SD: 2.9

Source: Author(s)

[a] Data from 99 water and sanitation committees (CAPYS).

of effect by a relatively independently assigned ''treatment'' on the outcome variable of interest (sustainability). By contrast, among communities that sought out support when they experienced problems with their water supply systems PCS provision can arguably be viewed as a function of sustainability, instead of the inverse. We have limited our investigation to tests of association between unsolicited PCS and various measures of sustainability; the 19 communities who received solicited support were not considered in our analyses.

3.3 Profile of the villages and the sustainability of their water supply systems

Village characteristics

A typical community comprised 63 households and 363 people. Most households in both departments have a dirt floor, adobe walls, and a brick roof. As in Peru and Ghana, however, there are some important differences between the communities in different departments, and also in the control and treatment groups. Households in Cochabamba villages seem to have a higher living standard than those in Chuquisaca. For example, while 63 percent of those we interviewed in Cochabamba have electricity service in the home, only 20 percent of those in Chuquisaca have electricity service, and only two out of ten households in Cochabamba reported annual incomes of less than US$400, as compared to four out of ten in Chuquisaca (Table 3.2).

Respondents in the household survey reported attending primary school (typically located within the community) for an average of 3 (Chuquisaca) or 4.5 (Cochabamba) years. Means of contact and travel to other communities are often restricted to radios and public or shared transport. The

Table 3.2: Village characteristics: Chuquisaca and Cochabamba

	Chuquisaca (n=50)		**Cochabamba (n=49)**		**Entire sample (n=99)**	
Mean (SD) household size	5.2	(2.2)	5.4	(2.5)	5.3	(2.4)
% with access to improved sanitation facilities	51.1		42.1		46.6	
% with fixed line and/or cellular phone in the home	1.2		14.8		8.0	
% with access to public phone in community	45.7		21.9		33.8	
% with electricity service in the home	20.0		63.4		41.7	
% of households with a motorcycle, car, and/or tractor	2.2		7.7		4.9	
Mean (SD) years of education completed by survey respondent	3.0	(1.3)	4.3	(2.0)	3.8	(1.7)
% of HHs reporting annual income of <US$100	40		17		28	
% of HHs reporting annual income of >US$400	13		17		15	

Source: Author(s)

vast majority of people interviewed work in agriculture (62 percent) or are spouses of people who do (18 percent). The median age of household survey respondents was 45 years.

Most of the communities participating in PROSABAR received household-level facilities. Among the 99 communities included in this study, 94 percent received piped water systems with household connections or yard taps. Public taps were installed in 27% of the communities. In 8 percent of the communities, some households—typically those who lived too far away to be served by piped networks—received private wells. The median per capita capital cost of the piped water supply infrastructure installed through the project was US$82. Most participating communities installed simple gravity systems; only 11 percent of the sampled communities had pumps on any part of their piped systems.

For most of the communities included in the study, the services provided by PROSABAR represent a considerable improvement over their previous water supply. Three quarters of the households interviewed in Chuquisaca, and 62 percent in Cochabamba, reported that they had relied on surface water sources or unprotected springs as their primary source of drinking water prior to installation of improved water supply through PROSABAR. Similarly, women who took part in our focus group discussions in each community indicated that water supply was the most pressing development issue for virtually every community at the time that PROSABAR began.

Water System Management and PCS

Almost all of the CAPYS interviewed for this study reported that their members were directly elected by the community. In one quarter of the CAPYS interviewed, committee members received regular pay for their services; in others, members were not paid. Three quarters of the communities in the study sample had a single system operator and one quarter had at least two. All the operators were male, and most had lived in their communities for 35 years. Almost 90 percent of the operators interviewed had held their post for more than one year, and 53 percent had been operators for five years or more. Roughly half the operators received a regular salary; one fifth were paid on a contract basis only (i.e., receiving funds when they carried out repairs or other non-routine activities); and 30 percent received no compensation. Operators were typically responsible for basic daily operation and minor repairs. The CAPYS and system operators shared responsibility for major repairs and for maintaining their community's water source. The CAPYS tended to be solely responsible for financial matters, including billing, collections, and the purchase of spare parts.

We define postconstruction support (PCS) as assistance provided to the water system operator and/or the CAPYS which, in turn, is expected to benefit the entire community, i.e., PCS is a community-level intervention. Within the study sample, the characteristics of communities that received solicited postconstruction support differ from those who received unsolicited or no PCS along several dimensions (Table ↱3.3). Households in such communities have higher rates of television ownership: 18–20 percentage points higher than those in no PCS and unsolicited PCS communities, respectively. In addition, 55 percent of households in communities with solicited PCS have in-home electricity service, compared to 40% in both unsolicited and no PCS communities. A typical respondent in a solicited PCS community has completed 0.7 year more of formal education as compared to those in communities receiving no support, and 1.2 years more education than the typical respondent in a community receiving unsolicited PCS. Taken together, these data suggest that communities whose households have comparatively more education and assets were more likely to seek out postconstruction assistance for their water systems. At the same time, none of these differences is statistically significant (all p values for tests of means and proportions are >0.10).

Communities that received unsolicited support have reported annual incomes that are 17 percent lower, on average, than those with either solicited or no PCS. This observation is consistent with the idea that organizations providing support might target communities where internal resources are expected to be relatively scarce. At the same time, communities that received unsolicited PCS appear quite similar to those that received no support with respect to most other characteristics summarized in Table 2. No significant differences were observed in the two groups' rate of ownership of radios, televisions, or vehicles, educational attainment, nor in the percentage of households with access to telephone or electricity services. Thus, whereas unsolicited PCS may have been targeted at particular types of communities by support organizations, we have no information on what criteria (if any) were used to select communities,

Table 3.3: Characteristics of communities receiving solicited versus unsolicited post-construction support[a]

	Solicited PCS (n=16)		Unsolicited PCS (n=22)		No PCS (n=58)	
Mean (SD) number of households in community	126	(78)	138	(125)	87	(71)
Mean (SD) household income (annual, Bs.)[b]	1740	(1160)	1440	(1160)	1755	(1110)
% owning a radio	94		92		90	
% owning a television	38		18		20	
% owning an automobile or tractor	8		2		5	
% with access to telephone service	40		45		43	
% with electricity service in home	55		40		40	
% using improved sanitation facilities	44		58		44	
Mean (SD) years' education of respondent	4.4	(4.2)	3.2	(3.3)	3.5	(3.2)
Mean (SD) distance to municipality (km)	42	(57)	35	(41)	44	(56)
Mean (SD) per capita cost of water system ($)	82	(51)	80	(63)	87	(97)
Mean (SD) age of water system (yrs)	7.1	(0.9)	7.2	(1.3)	6.9	(1.2)

Source: Author(s)

[a] Data from 2365 households.

[b] Households assigned value of midpoint of one of seven ordinal categories

nor any statistically significant associations between receipt of unsolicited PCS and community characteristics.

Sustainability

The water systems installed by PROSABAR in the sampled communities were found to be performing remarkably well with respect to several different indicators of sustainability:

- *Recent system functioning*, as measured by: (1) within each community's sample of households, the percentage of water connections that were working at the time of the field visit, and (2) the number and duration of reported breakdowns during the six months prior to the field visit.
- *User satisfaction*, measured on an ordinal scale that represents water system operation and maintenance; the performance of the water and sanitation committee (CAPYS); and the taste, color, odor, and perceived safety of the water supply.
- *Perceived likelihood of future system functioning*, measured by (1) a composite variable of subjective judgments of future sustainability made by the system operator and CAPYS members, and (2) leaks observed in tanks and distribution pipes in the system.

System functioning[21]

The accounts of residents, system operators, and water committee members suggest that the systems installed by PROSABAR within the sampled communities were faring much better than the literature on rural water supply in developing countries would predict. For example, of the 2,279 households interviewed who had private connections to piped systems, 95 percent reported that their connections were functioning.

This is not to say that PROSABAR communities faced no challenges with the functioning of their water supply systems. In roughly half (54 percent) of the 99 communities included in the study, operators had reported at least one system breakdown during the six months prior to the field team's visit (Table 3.4). Household members and participants in the women's focus group discussions reported breakdowns more often than this, apparently because residents classified as "breakdowns" events of low pressure that resulted in their families' receiving limited or no supply. This classification is probably also the source of the discrepancies observed in responses about the typical duration of individual breakdown events.

User satisfaction

Respondents to the household survey reported general satisfaction with the operation and maintenance of their systems installed through PROSABAR. Across all communities, 82 percent reported they were "satisfied" or "very satisfied" with their system's operation and maintenance (O&M) regime, and 78 percent reported they were "satisfied" or "very satisfied" with the performance of their water and sanitation committees. User-reported satisfaction was similarly strong with respect to the quality of water provided through PROSABAR systems. More than 95 percent of households expressed satisfaction with the color, odor, taste, and safety of their water

Table 3.4: Number and typical duration of system breakdowns during six months prior to interview, as reported by operators and residents in study communities

	Number of breakdowns	**Typical duration of breakdown (days)**
System operators (*n*=96)	Median: 1 Mean: 2.1 SD: 3.2	Median: 1 Mean: 4.2 SD: 12.2
Household members (*n*=2,365)[a]	Median: 2 Mean: 3.0 SD: 6.4	Median: 2 Mean: 9.8 SD: 36.7
Women's focus group participants (*n*=776) [a]	Median: 2 Mean: 2.9 SD: 4.3	Median: 2 Mean: 15.8 SD: 35.1

Source: Author(s)

[a] Values are weighted by community.

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[21] Given that 96 percent of the respondents interviewed had private connections to piped water systems, the findings in this section focus exclusively on this level of service; data from respondents who were served exclusively by public taps or wells have been omitted.

supply during the dry season. Satisfaction levels were somewhat lower for service during the rainy season, but still exceeded 75 percent.

The quantity of water supplied through PROSABAR systems, however, was a source of dissatisfaction for many community members. Indeed, two thirds of the women who participated in focus group discussions in both departments felt that the quantity of water provided by PROSABAR systems was insufficient or "just enough to meet community needs." In addition, almost one fifth of the women's groups concluded that they were "unsatisfied" or "greatly unsatisfied" with their water service overall. Given the generally positive attitudes toward water quality and system maintenance, this overall view is likely to reflect concerns over limited supplies.

Household survey data indicate that 25 percent of the respondents with private piped connections in their homes also used a secondary source of water such as a river or lake. As discussed later in this chapter, virtually all communities charged users a flat monthly fee, rather than a volumetric charge, for water supply service. Household dissatisfaction with the quantity of water available from the PROSABAR systems thus seems to have reflected a pure shortage of supply rather than an affordability issue.

Prospects for future system functioning

It thus appears that a substantial proportion of communities have already reached the full capacity of the water systems installed through PROSABAR. Twenty-four percent of the CAPYS interviewed in Chuquisaca, and 30 percent in Cochabamba, reported that they did not currently allow new connections to their piped water systems. Among these committees, 40 percent said that the main constraint they faced was a shortage of water to meet increased demand, while 30 percent said that their main constraint was a shortage of financial resources to expand the distribution network. These data are consistent with reports that roughly half the communities in Chuquisaca, and 36 percent in Cochabamba, experience regular conflicts over water use rights among the families living there.

Operators in 18 percent of the communities said that they had experienced changes in the quantity of water supplied per day during the dry season since their systems were constructed. Comparing these with the 82 percent of communities whose operators report no decline in water supply, no significant differences are apparent in terms of maintenance indicators (percent of systems with leaking pipes or storage tanks), increased demand on the system (percent that have extended the system since construction), or postconstruction support received. It is thus unclear whether such challenges are the result of leaky pipes, poor maintenance, or a diminishing water source. Meanwhile, eight communities reported an increase in water supplied by their piped systems since installation, suggesting that improvements or extensions (e.g., the addition of a new water source) may have been made to the original design.

Consistent with their high degree of satisfaction with operation and maintenance, most of the households interviewed were sanguine about the sustainability of their water systems in the short term (Table 3.5). Members of the water committees, too, were generally positive about short-term sustainability, but they expressed greater doubt about the community's ability to maintain their water infrastructure beyond five years.

Finances

The relative pessimism of committee members may partly reflect their greater awareness of the precarious financial position of many of the water systems installed through PROSABAR. In

Table 3.5: Perceived future sustainability of piped water systems as per household survey respondents, CAPYS members[a]

	"Do you think the water system installed by PROSABAR will still be functioning after…" (% of responses)		
	…one year?	…five years?	…ten years?
Household members (*n*=2,365)[a]	Yes: 95 No: 2 Not sure: 2	Yes: 77 No: 11 Not sure: 13	Yes: 50 No: 18 Not sure: 31
CAPYS members (*n*=776)[a]	Yes: 86 No: 11 Not sure: 3	Yes: 63 No: 28 Not sure: 8	Yes: 28 No: 54 Not sure: 18

Source: Author(s)

[a] Values are weighted by community.

principle, every community was required to accept financial responsibility for the upkeep of its water supply system. Across both departments, we found that a majority of CAPYS were collecting regular payments from users, but that the amounts charged for water supply were nominal and almost certainly below the cost of service provision, once depreciation is taken into account (Table 3.6). Given median per-capita capital costs of US$82 for PROSABAR systems, and assuming a capital recovery factor of 0.12, per-household monthly costs of operations, maintenance, and depreciation would be on the order of US$6 per month. To cover operation, maintenance, and minor repairs only, monthly household payments of US$1–1.80 would be required, or 2.6–7 times more than the CAPYS are collecting. Moreover, despite the fact that Bolivia experienced 5 percent inflation during 2005, only 13 percent of CAPYS had increased their tariffs during the year; 60 percent reported that their usage fees had not changed, and 27 percent had actually lowered their tariffs.

Table 3.6: Tariff structure for households with private water connections

	Chuquisaca (n=49)	**Cochabamba (n=50)**	**Entire sample (n=99)**
% of communities levying volumetric charges	0%	3%	2%
% of communities levying flat monthly or bimonthly charges	93%	86%	89%
% of communities not charging regularly/at all for water supply	7%	11%	9%
Mean, median monthly household fee, among communities using flat charges[a]	US$0.39 US$0.25	US$0.33 US$0.25	US$0.36 US$0.25

Source: Author(s)

[a] In Chuquisaca, 5 of the 50 communities (10%) included in the sample have installed meters on their piped water systems; in Cochabamba, this number was 17 of 49 (35 percent). Even among these communities, however, it appears that most households pay a flat monthly fee per household.

3.4 Explaining variation in sustainability: regression analysis

As described above, overall it appears that measures of current system performance within PROSABAR communities are quite favorable. Only five percent of communities visited by the study field teams had systems that were entirely out of operation. Levels of satisfaction with current water supply services are generally high, and most community members and water committees believe that their water systems will continue to function for the next several years. In short, limited variation in the values of the sustainability indicators exists, which makes it difficult to identify statistically significant associations between sustainability and various independent variables, including those related to post-construction support.

We explored a range of permutations relating independent variables to measures of sustainability, using multivariate regression techniques. The variables included in our final models are listed in Table 3.7.[22]

Table 3.7: Variables used in regression analysis

Variable name	***Data source***	***Description***
System functioning	Operator/HH survey, observation	1=100% working; 2 = 90–99%; 3 = 0–89%
Distribution system leaks	Engineering inspection	1=Leaks observed in distribution system 0=No leaks observed in distribution system
Revenue sufficiency	CAPYS interviews	1=Revenues cover O&M, 0=otherwise
HH satisfaction 1	HH survey	Percentage of households saying that they are 'very satisfied' with the performance of their community water committee (CAPYS)
HH satisfaction 2	HH survey	Percentage of households saying that they are 'very satisfied' with the operation & maintenance of their water system
Distance	HH, operator interviews	Travel time to municipal capital (hours)
Income	HH survey	Monthly household income in $US10s (midpoint of 7 ordinal categories)
Engineering PCS	CAPYS and operator interviews	1=Community received unsolicited technical PCS visits; 0=Otherwise[a]
Administrative PCS	CAPYS and operator interviews	1=Community received unsolicited nontechnical PCS visits; 0=Otherwise[a]
Operator workshops PCS	Operator interview	1=Operator received unsolicited PCS training workshops, 0=Otherwise*
Pump on system	Operator, CAPYS interviews	1=Water system includes pump, 0=Otherwise

(*continued on next page*)

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[22] A number of other dependent and independent variables were explored in the regression analysis but were ultimately eliminated because of poor model fit.

Table 3.7: Variables used in regression analysis *(continued)*

Variable name	***Data source***	***Description***
Community contribution	HH, CAPYS, and operator interviews	Mean value of per-HH capital cost paid (Bs.)
System age	CAPYS and operator interviews	Age of system (yrs)
Service Interruptions	HH survey	Number of system interruptions in past 6 months
Social capital	HH survey	% of HHs that report that "many people in the community will help you if you need"
Alternative source	Women's focus group	% of households using a secondary water source
Department	Secondary data	0=Cochabamba 1=Chuquisaca

Source: Author(s)

[a] Most communities who received unsolicited PCS reported receiving such support once every two to three years, i.e., on two or three occasions since the construction of their water systems was completed. Quantity effects were not significant for any PCS variable.

As noted above, another important shortcoming exists with respect to statistical analyses of our data. We do not know whether postconstruction support was allocated randomly by public agencies and civic organizations to communities within their jurisdiction; nor do we know of any specific criteria used to target communities for receipt of unsolicited PCS (other than geographical location). As shown in Table 3.3, some evidence of targeting exists with respect to mean income values within each community. Nevertheless, geography (at the Department level) is the only criterion that consistently appears in a first-stage regression equation designed to explain ''exposure'' to unsolicited PCS; no other selection process is in evidence. As such, we include Department, along with a number of other factors that we suspect might influence the treatment effect, as covariates in the regression analyses presented below. We emphasize the importance of considering these results along with those of the matched pairs analyses presented below in drawing substantive conclusions from our study findings.

We modeled a variety of sustainability-related indicators using multivariate regression techniques. The reduced model results of these analyses are presented in Table 3.8 and Table 3.9. With respect to water system operation and maintenance, models 1 and 2 suggest that, all else held constant, older systems were significantly more likely to have taps out of order (model 1), whereas communities located at greater distance from municipal capitals were more likely to have leaking distribution systems (model 2). All forms of PCS are positively associated with system functioning, with one significant association at the 0.10 level. All else held constant, communities that received administrative post-construction visits were more likely to have a higher fraction of taps operational at the time of the field visit (model 1). Models explaining frequency and duration of system breakdown (our other technical performance variables), as well as household and CAPYS perceptions of future system sustainability, had very little explanatory power. Interaction terms designed to test for effects of PCS in the nine communities that received multiple types of support were not significant in any of the models.

Model 3 examines revenue sufficiency across the communities. Each CAPYS was asked to share records regarding expenditures incurred and revenues collected by the committee in the year prior

Table 3.8: Regression analysis results: system functioning[a]

	(1) % HH Taps functioning (1=100% working, 2 = 90–99%, 3 = 0–89%)		(2) Leaks in distribution system (1=leaks observed, 0=otherwise)		(3) Revenue sufficiency (1=Revenues cover O&M, 0=otherwise)	
Model form	*Ordinal logit*		*Binary logit*		*Binary logit*	
Intercept	–8.36 –6.44	(2.77), (2.67)	–1.90	(2.22)	4.95	(2.16)
Distance to municipality (hours)	0.32	(0.29)	0.63***	(0.23)	–0.15	(0.18)
Median HH Income	–0.07*	(0.04)	–0.02	(0.03)	–0.03	(0.03)
System age	0.45*	(0.27)	0.11	(0.27)	0.42*	(0.23)
Pump on the system					–1.83	(0.96)
Mean capital cost paid per HH (Bs.)	–0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Engineering PCS	–1.76	(1.13)	–1.46	(0.95)	0.94	(0.76)
Administrative PCS	–2.34*	(1.34)	–0.80	(1.27)	1.57	(1.23)
Operator workshop	–1.13	(0.83)	–1.77*	(0.99)	0.16	(0.66)
Department	–1.88**	(0.71)	0.41	(0.75)	0.79	(0.64)
Quasi R^2 value	*0.29*		*0.22*		*0.17*	
Number of observations	*78*		*78*		*78*	

Source: Author(s)

[a] Robust standard errors in parentheses. Most communities who received unsolicited PCS reported having such support once every 2 to 3 years, i.e. on two or three occasions in the period since construction of their water systems was complete. Quantity effects were not significant for any PCS variable. Asterisks denote $0.05 < p \leq 0.1$. Double asterisks denote $0.01 < p \leq 0.05$. Triple asterisks denote $p \leq 0.01$.

to the field visit. Only 40% of the CAPYS had records available for review; for the other 60%, interviewers worked with committee members to estimate these values. Given the heavy reliance on recall data, the interviewers felt that only a qualitative assessment of each CAPYS could be established (rather than an estimated working ratio). Communities were thus grouped into two categories, those in which revenues were perceived to fully or almost fully cover operating costs (1) and those in which the gap between costs and revenues was thought to be at least 10% (0). The logit model results suggest that communities with older systems, and the 8% using pumps, are facing greater challenges in covering their operation and maintenance costs through user fees. All forms of PCS are positively associated with financial sustainability. Although not statistically significant, the magnitude of the average effect for administrative ''circuit rider'' visits is large; a community that received this type of support was 4.8 times more likely to be classified as covering its operating costs as compared to one that had not.

Models 4 and 5 explore household satisfaction with the operation and maintenance (O&M) of water systems installed through PROSABAR and the performance of the community water and sanitation committee, respectively. After being questioned about the features of their water supply situation (e.g., hours of service, pricing and payment) respondents in the household survey were asked whether they were generally "very satisfied," "satisfied," "somewhat dissatisfied," or "very dissatisfied" with each aspect of their water supply service. (A "don't know" option was not read out to the respondent but could be selected by the enumerator if the respondent was unable to provide an answer.)

Both models suggest a statistically significant association between household satisfaction and relevant water service characteristics, such as whether all taps on the piped system were working order, the extent of reliance on secondary (nonpiped) sources of water, and the number of service interruptions reported in the 6 months prior to data collection.

All else held constant, communities with higher levels of assessed mutual trust also have higher rates of satisfaction with both O&M and CAPYS. In addition, there is some evidence of an "ownership" effect in water service delivery. All else held constant, the percentage of households expressing satisfaction with O&M and CAPYS performance increases with the amount of the average household contribution toward the initial capital costs of the water systems (although the magnitude of this effect is small). This observation stands in contrast to the results in model 3, which is not consistent with the idea that a community's ability to mobilize capital cost contributions at the time of construction is a good predictor of financial sustainability during the operation and maintenance period.

The provision of engineering-oriented postconstruction visits and operator workshops has no statistically significant association with household satisfaction. Communities that have received administratively oriented postconstruction visits, however, do have a higher level of satisfaction with

Table 3.9: Regression analysis results: household satisfaction[a]

	(4) % HHs "Very Satisfied" w/ System O&M		**(5) % HHs "Very Satisfied" w/CAPYS**	
Model form	*OLS*		*OLS*	
Intercept	34.7	(9.6)	20.8	(12.8)
Engineering PCS	2.2	(4.4)	4.3	(5.8)
Administrative PCS	11.5*	(6.3)	13.3*	(8.1)
Operator workshop	–2.9	(4.9)	1.0	(5.4)
Number of system interruptions in past 6 months	–2.2***	(0.7)	–1.0	(0.9)
All taps functioning (dummy)	10.5***	(3.7)	10.5**	(4.9)
% of households using secondary water source	–0.2**	(0.8)	–0.03	(0.1)
Community trust (% saying "many people will help you if you need it")	0.6***	(0.12)	0.61***	(0.16)
Mean value of per-HH capital cost paid (Bs.)	0.04***	(0.01)	0.05***	(0.02)
Department	–6.7	(4.6)	–8.22	(6.07)
Adjusted R^2 value	*0.43*		*0.28*	
Number of observations	*83*		*83*	

Source: Author(s)

[a] Robust standard errors in parentheses. Asterisks denote $0.05 < p \le 0.1$. Double asterisks denote $0.01 < p \le 0.05$. Triple asterisks denote $p \le 0.01$.

O&M and with the performance of their CAPYS. All else held constant, receipt of administrative PCS visits is associated with an average 12 to 13 percentage point increase in the share of households expressing satisfaction with system O&M and CAPYS performance ($p = 0.08$).

3.5 Testing for the effects of post-construction support: matched pair analysis

Another approach to assessing the impact of PCS on system performance is to create sets of “treatment” and “control” communities that are similar with respect to the socioeconomic, demographic, and geographic characteristics that are suspected to influence water system sustainability. Matching is a technique enjoying renewed popularity in quasi-experimental research, i.e., situations in which random assignment of treatments to observations is not possible (Heckman, Ichimura, and Todd 1997). By creating pairs of treatment and control communities that are matched on a set of observed covariates that are believed to have relevance to the outcome variables of interest, systematic differences between the full treatment and control groups can be addressed.

As noted above, we have no information regarding the criteria used to select communities for PCS intervention (other than geographic location). Our matching algorithm was thus based on a conceptual model of selection whose covariates included: number of households within the community; median reported annual household income; distance from the community to the municipal capital (measured in hours); age of the piped water system (< 6 years, 6–8 years, or >8 years); per capita cost of the piped water system installed through PROSABAR; value of per-household cash contribution made toward system construction; percent of households with access to telephone services; percent of households who expressed trust in their fellow community members (a social capital measure); and department (Cochabamba or Chuquisaca). Whereas matching would ideally have been carried out before the PCS intervention, the only data available for the analysis were those describing the communities at the time of the field activities. In addition, it is important to note that matching cannot control for differences in unobservable characteristics of the communities or water systems that may affect the impact of postconstruction support on the dependent variables of interest.

A variety of approaches to matching treatment and control observations are found in the literature, but most are of the “propensity score” or “nearest neighbor” types (Rosenbaum and Rubin 1983). Propensity score matching is not particularly appropriate in our study; no information regarding the criteria used to target communities for the PCS programs was identified. Moreover, initial analyses identified no systematic selection process other than geography (i.e., location in an area served by the supplying municipality or NGO) at work among the communities selected to receive support. Instead, a variant of nearest-neighbor matching in which the difference (or “distance”) between values of each covariate among all the communities in the dataset was computed. Ranks were then assigned to the absolute distances for each covariate. Finally, the sum of these ranks across the whole set of matching characteristics was minimized. A more detailed description of the matching algorithm employed and a comparison with an alternative nearest-neighbor matching technique is provided in Appendix 3.1.

In creating our treatment and control groups, we attempted to isolate the impact attributable to each type of postconstruction support (engineering visits, administrative visits, and operator training workshops) by comparing communities that received only that type of PCS with communities that received no support. Nine communities that received more than one type of PCS were eliminated from the sample. The matched pair analysis thus responds to a somewhat different question than that posed in the regression analyses in Section 3.4. The regression models assess the extent to which communities that received a particular type of unsolicited PCS (engineering visits, administrative visits, or operator training workshops) have better water system performance as compared both to communities that received no support, as well as to communities that received different kinds of PCS. Each matched pair analysis assesses the extent to which communities that received a particular type of PCS have better water system performance as compared only to communities that received none of the PCS interventions explored in our study.

Assuming that the covariates used for matching account for the majority of variation in water system performance other than that attributable to postconstruction support, this procedure allows for the direct comparison of performance measures among communities that received some versus no PCS. Such comparisons take the form of nonparametric statistical tests, in particular one-way ANOVA and the Kruskal-Wallis test. The results in Table 3.10 pertain to five performance measures and three types of unsolicited postconstruction support.

As with the regression analyses, no effect of engineering-oriented visits is found on the comparison of treatment versus control villages. Also consistent with the regression analyses, household satisfaction with both system operations and maintenance and the functioning of the water committee CAPYS is significantly higher among communities that received administrative PCS visits. With respect to operator workshops, the significant (negative) association with system leaks observed in the regression analysis does not emerge in the matched pair analysis, but operator workshop training is significantly associated with rate of tap functioning.

Impacts of PCS on water committee functioning

Both the regression and the matched-pair analysis results suggest that administrative visits and operator training have enhanced user satisfaction with O&M and water committee performance,

Table 3.10: Results of matched-pair analyses for unsolicited PCS interventions[a]

Dependent variable test of significance		**Engineering visits**	**Administrative visits**	**System Operator Training**
Tap functioning (1=100%, 2=90–99% 3=0–89%)	Anova (F)	0.3	1.0	6.5*
	Kruskal-Wallis (X^2)	0.2	1.1	6.3**
# of breakdowns in past 6 months (1=zero, 2=1–2, 3=3+)	Anova (F)	0.1	0.4	0.6
	Kruskal-Wallis (X^2)	0.1	0.5	0.5
Presence of leaks in distribution system and/or water tank	Anova (F)	0.0	0.1	1.2
	Kruskal-Wallis (X^2)	0.1	0.1	0.1
% of households “very satisfied” with system O&M	Anova (F)	0.3	6.7***	0.0
	Kruskal-Wallis (X^2)	0.9	7.8***	1.4
% of households “very satisfied” with CAPYS	Anova (F)	2.0	6.1***	1.0
	Kruskal-Wallis (X^2)	2.6	8.9***	1.7

Source: Author(s)

[a] Asterisks denote $0.05 < p \leq 0.1$. Double asterisks denote $0.01 < p \leq 0.05$. Triple asterisks denote $p \leq 0.01$. Degrees of freedom range between 46 and 50 for one-way Anova tests (degrees of freedom for all Kruskal-Wallis tests equal one).

ostensibly by affecting the way that water systems are managed. We thus examine the links between post-construction support and several management-related indicators (Table 3.11), with the assumption that these can be viewed as proximal indicators of sustainability.

This analysis suggests a potential link between PCS and management practices that are generally believed to promote water system sustainability. Evidence for these associations must be interpreted carefully, given our very small sample sizes and the limited variation in both the dependent and independent variables of interest. It is also important to remember that PCS has been supplied to communities in these departments by several different government and NGO groups, with likely variations in quality of support that could not be captured by our analysis. With these caveats, the evidence suggests that those who have received periodic "injections" of capacity building—particularly related to administrative and financial functions of the CAPYS—may have been performing better than those that had not benefited from such support.

All CAPYS that had received unsolicited visits providing non-technical support reported (and could provide documentation of) regular monthly meetings with households; only 64 percent of the control communities reported such meetings. Almost half of the CAPYS in treatment communities were paid for their services, as compared with only 9 percent of those in control communities. In addition, CAPYS that had received unsolicited PCS appear to have been on a somewhat more solid financial footing—as evidenced by their higher rates of regular bill collection (33 percent

Table 3.11: Comparison of performance indicators between CAPYS receiving unsolicited administrative PCS ("treatment") and CAPYS receiving no PCS ("control")[a]

	Treatment communities	**Control communities**	**Tests of significance**
% holding regular monthly meetings with community members	100%	64%	Anova (F): 4.8** Kruskal-Wallis (X2): 4.3**
% of committees in which members are paid for service	44%	9%	Anova (F): 5.7** Kruskal-Wallis (X2): 4.9**
% of committees that collect tariffs from users >4 times per year	33%	4%	Anova (F): 5.5** Kruskal-Wallis (X2): 4.8**
% that increased tariffs in year prior to interview	38%	5%	Anova (F): 3.3* Kruskal-Wallis (X2): 2.5
Mean, median % of households in arrears at time of interview	Mean: 1.8 Median: 0.0	Mean: 29.5 Median: 13.0	Anova (F): 2.8* Kruskal-Wallis (X2): 2.4
Mean, median % of connected households who received a fine for late payment in year prior to interview	Mean: 1.7 Median: 0.0	Mean: 1.4 Median: 0.0	Anova (F): 0.0 Kruskal-Wallis (X2): 0.2
Mean, median % of connected households who were disconnected for non-payment in year prior to interview	Mean: 0.0 Median: 0.0	Mean: 3.2 Median: 0.0	Anova (F): 2.1 Kruskal-Wallis (X2): 2.6*

Source: Author(s)

[a] Asterisks denote $0.05 < p \leq 0.1$. Double asterisks denote $0.01 < p \leq 0.05$. Triple asterisks denote $p \leq 0.01$. Degrees of freedom range between 46 and 50 for one-way Anova tests (degrees of freedom for all Kruskal-Wallis tests equal one).

versus 4 percent) and tariff increases in the year prior to our field study (38 percent versus 5 percent).

There is no evidence that CAPYS that received administrative PCS visits were more likely than committees in control communities to levy fines on nonpaying households (although average disconnection rate in control communities are comparatively higher). Nevertheless, the median percentage of households reported to be in arrears on their water bills at the time of our fieldwork was substantially lower than that of control communities. In short, it appears that CAPYS that had received administrative PCS visits were operating with more of a small-business approach—providing salaries to their "employees," maintaining regular communication with "customers," and paying greater attention to financial sustainability issues—than the committees that had not received this type of support.

3.6 Discussion and Conclusions

A principal finding of our research is that the vast majority of rural water systems installed under PROSABAR that were included in the study sample were functioning quite well. Five or more years after system construction, only five percent of the communities studied had systems that were not operating. Households in the sample communities reported substantial improvements in their water supply as a result of the project and were largely satisfied with the services they were receiving. Most community members and water committees were confident that their water systems would continue to function for the next several years. Water committees appeared to be generally functional, and system operators were continuing in their posts for several years. It appears that the strong emphasis on community participation, "demand filters" such as cash and in-kind contributions, and the technologies employed in PROSABAR have indeed yielded more sustainable outcomes than those typically portrayed in the literature on rural water supply services in developing countries.

These findings are particularly heartening given that the post-construction support system that was developed by the architects of PROSABAR's *Red de Saneamiento Básico* was not sustained beyond the network's pilot phase. Indeed, a second important insight from this study is that municipal governments in Cochabamba and Chuquisaca have been unable to sustain the provision of PCS that was envisaged in the design of PROSABAR. This experience is consistent with the conventional wisdom in the rural water sector that marshalling public finance to build new systems is easier than sustaining investment to maintain existing assets.

In some areas, the void in post-construction support for rural water supply that was left by municipal governments upon termination of the *Red de Saneamiento Básico* has been filled by NGOs such as Plan International and CARE. Anecdotal evidence suggests that in several developing countries, NGOs are important actors in PCS programs in rural water supply (Komives et al. 2007; Prokopy et al. 2007; and the other case studies in this volume). To the extent that PCS is generally found to be important for the sustainability of rural water investments, it seems necessary to understand the strengths and weaknesses of, and policy supports needed for, effective NGO-mediated PCS programs.

The uniformly good performance of the water systems studied, combined with the various data quality problems noted above, provide a challenging context in which to examine the potential impacts of post-construction support on system performance. In addition, our study is limited to the evaluation of post-intervention measures across the treatment and matched comparison communities. Whereas some efforts were made to collect information about the communities prior to the installation of the improved water systems, some of these data are likely to be vulnerable to recall bias. Future research in this area would be greatly strengthened if designed with a set of baseline measures, random assignment of the PCS ''treatment,'' and follow-up measures of system functioning.

Nevertheless, the data are consistent with the hypothesis that, at the margin, certain types of post-construction support have positively affected rural water systems in Cochabamba and Chuquisaca. In particular, periodic visits from management specialists were associated with a higher rate of household tap functioning, as well as greater user satisfaction. Though the precise mechanisms by which non-technical PCS influences user satisfaction are unknown, matched-pair analysis suggests that the water committees that received this support tended to use administrative practices that are conceptually linked to more sustainable outcomes (e.g., periodic price increases, regular meetings with community members). Notably, such practices are also often perceived as being particularly difficult to implement in low-income communities.

We found no evidence that system performance was affected by visits from engineering-oriented specialists. However, matched-pair analysis indicates significant differences in outcome measures between communities whose operators were invited to attend postconstruction training workshops and those who received no postconstruction support. In the communities whose operators had attended workshops, a significantly higher percentage of household taps were functioning at the time of our field visit. To the extent that the costs and logistical requirements of organizing periodic operator workshops are probably much lower than those of establishing and maintaining a "circuit rider" program of technical visits, these findings could be viewed as good news for practitioners charged with designing PCS systems.[23]

An interesting question arises about the different inferences about operator workshops emanating from the regression versus matched pair analyses. As noted above, the two approaches answer different questions. Matched pair analysis is used to control for characteristics extant in the sample communities at the time of the PROSABAR project implementation such that the ''treatment'' of postconstruction support more closely resembles a randomized trial. Our analyses isolate the effects of particular kinds of postconstruction support as compared to receiving no PCS at all. By contrast, our regression analyses include some variables related to the postconstruction situation (e.g., system age, current measures of social capital). It compares the performance in communities that received a particular type of PCS to those who received either another type of PCS, or no support at all.

Given these differences in analytical strategy, it is not surprising that the results of the two approaches differ to some extent. Taken together, they raise a set of interesting hypotheses that cannot be tested with our data but which warrant further investigation. For example, it could be that the majority of ''technical'' problems with water system performance in most communities are actually a function of insufficient revenues for operation and maintenance. If true, one would expect that, among the PCS programs investigated, administrative visits would have the greatest contribution toward system performance. Operator workshops might thus have a significant impact on performance as compared to no PCS at all, as found in the matched pair analyses, because some discussion of financial sustainability during the workshops was translated into

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[23] It is of course possible that other benefits of circuit rider programs (such as the opportunity for technical staff to exchange information directly with community and water committee members) exist but were not captured in our analysis.

improved revenue collection practices at the community level. Compared to administrative visits that (1) focus explicitly on financial and administrative matters and (2) involve multiple members of the water committee rather than just a single operator, however, workshops may have a much less pronounced effect on performance (consistent with the regression analysis findings presented in Section 3.4).

Overall, of course, the data suggest a very high level of functioning among systems in sampled communities—which, one could argue, draws into question the value of any supply-driven spending on post-construction support at all. At the same time, it is important to note that the systems we evaluated range between five and eight years in age, which could be viewed as too short a period over which to evaluate their sustainability. We found a number of troubling trends in the sample communities (e.g., limited cost recovery, declining water supplies) that may portend real challenges for water system management in the near future. To the extent that variability in performance increases over time, so too may the value of post-construction support efforts.

APPENDIX 3.1: MATCHING PROTOCOL

In analysis of results from quasi-experimental research designs, matching of observations on similar characteristics is now widespread. Matching is an attractive option on two levels: 1) it has intuitive appeal because it allows comparison of similar communities, groups, or individuals, and 2) it offers the possibility of control over specific characteristics thought to influence program effectiveness. When random assignment of treatments to observations is not possible, matching holds promise for interpreting outcomes, especially when two clearly distinct groups of observations exist.

In Bolivia, villages receiving rural water supply development projects can be separated into several different groups corresponding to the type of PCS they received: villages that received 1) unsolicited technical PCS visits, 2) unsolicited non-technical PCS visits, 3) operator training workshops, 4) some combination of these forms of PCS, or 5) no unsolicited PCS. As a result, matching holds promise for comparing the effect of these various PCS "treatments" on the sustainability of the water systems both physical (breakdowns and leaks) and perceived (household satisfaction).

As a consequence of important theoretical contributions from the field of econometrics, use of matching techniques now typically focuses on different variations of nearest-neighbor matching or propensity score matching. Applied to our sample, the latter technique would produce a univariate score (using logistic regression methods) for communities that would reflect the probability that a community received a particular form of post-construction technical assistance, based on village, regional, and project characteristics. Because communities in the sample were chosen to receive treatments based primarily upon their geographic remoteness, propensity score matching is not really justified.

Nearest-neighbor matching methods include caliper matching, distance (absolute or squared differences) matching, cluster analysis, benchmark matching, and optimal matching. Caliper matching pairs observations within a specified range of variation, so statistical power can be reduced if the observation set shrinks too much. Benchmark group matching selects control units falling close to the treatment unit on some multivariate distance (index) measure. No definitive review has been done that compares the strengths and weaknesses of each of these matching methods.

To evaluate the effects of the various PCS programs, we develop an optimization algorithm for creating "nearest-neighbor" matches. Instead of minimizing the absolute or squared differences over a set of characteristics, as could be done with more traditional matching techniques, we assign ranks to the absolute differences and then minimize the sum of these ranks across the whole set of matching characteristics. For example, if we are trying to match the number $\alpha = 3$ with one of those in the set of five numbers below:

$$\beta = \{1,3,4,4,7\},$$

we first calculate absolute differences: $\delta_{\alpha 1} = |1 - 3| = 2$, $\delta_{\alpha 2} = |3 - 3| = 0, \ldots, \delta_{\alpha 5} = |7 - 3| = 4$. From the vector of differences [2, 0, 1, 1, 4], we generate difference ranks:

$$[4,1,2,2,5].$$

Our objective is to minimize rank differences, so we match α and β_2. This procedure is extended to matches on all chosen variables, where the individual variable ranks are summed. The match is then made between the two observations with the smallest rank sum.

Use of this method reduces the probability of creating matches between villages that are quite different on one particular characteristic but similar on all others (thus having relatively small absolute differences). In addition, this nearness weighting removes the problems of scaling that can occur when the matching characteristics are measured by vastly different metrics. (Alternatively, as discussed later, one could employ z-score matching, which adjusts for these scaling differences based on the standard deviation of the variable in question.)

We formulate this as a simple assignment-with-replacement optimization problem:

$$MinZ = \sum_{i=1}^{n} \sum_{j=1}^{m} \quad \sum_{k=1}^{K} rank\left|(\alpha_{ik} - \beta_{jk})\right| \; * x_{ij}$$

$s.t.$ $\sum_{j=1}^{n} x_{ij} = 1$ for all $i = 1,\ldots,n$ (each treatment observation used once), where

$x_{ij} = 1$ if treatment village i assigns to control village j, 0 otherwise;

α_{ik} = value of variable k for treatment observation i;

β_{jk} = value of variable k for control observation j;

rank($|\alpha_{ik} - \beta_{jk}|$) = rank of absolute difference between observation i and observation j on matching variable k.

It is also possible to relax the restriction that each treatment unit receive only one control match (1-n matching) by changing the constraint listed above to the following:

$\sum_{j=1}^{n} x_{ij} = p$ for all $i = 1,\ldots,m$ (each control village used at most once),

where p is the number of control units to match to each treatment unit.

We use the following k variables in our matching algorithm, since they are thought to be relevant to the sustainability of the systems:

- Number of households in community
- Age of piped water system (three-level categorical variable for <6 years, 6–8 years, or >8 years)
- Per capita cost of piped water system
- Value of per household cash contribution for construction
- Percent of households with access to telephone service
- Percent of households expressing trust in fellow community members
- Department (Cochabamba or Chuquisaca)
- Distance from community to the municipal capital (hours)
- Median reported annual household income

Once the matching sets are created, we calculate an average treatment effect by comparing the mean or median sustainability scores of the two groups. Anova and Kruskal-Wallis tests can be applied to determine the statistical significance of this difference.

Z-score matching

Instead of simply relying on optimal matching between units on the basis of rank differences, one might also use some other "distance" measure, such as the z-score. Mathematically, the problem becomes:

$$MinZ = \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{K} \left|(z_{ik} - z_{jk})\right| * x_{ij}$$

$s.t. \sum_{j=1}^{n} x_{ij} = 1$ for all $i = 1,\ldots,n$ (each treatment observation used once), where

$x_{ij} = 1$ if treatment village i assigns to control village j, and 0 otherwise;

α_{ik} = value of variable *k* for treatment observation i;

β_{jk} = value of variable *k* for control observation j;

$|(z_{ik} - z_{jk}|)$ = z-score difference between observation *i* and observation *j* on matching variable *k*.

The z-score of the unit on variable k is calculated according to the following formula:

$z_{ik} = \dfrac{x_i - \bar{x}}{s_x}$, where x_i is the value of variable *k* for unit *i*, $\bar{x}$ is the sample mean of variable *k* and s_x is its standard deviation.

Because of the limited number of "treatment" communities as compared to "control" communities, we employed 1-to-*n* matching in which each community that received unsolicited post-construction support was paired with up to five control communities that received no support. We carried out several variations of the matched-pair analysis (e.g., z-score matching), and none of these alternative formulations produced substantively different findings. The matching and statistical analysis strategies presented here were ultimately selected because they generated fewer problems (e.g., vulnerability to outliers) and took the greatest advantage of the available data. Following each round of preliminary matching, the data were "trimmed" in order to eliminate relatively poor matches (in this case, those with a cumulative distance measure above the 90th percentile of all distance measures in the matched pairs). Trimming increases the efficiency of the matching protocol.

Thus, as discussed above, use of z score or rank matching is not most efficient as measured by the sum of squared errors, a finding that generally applies to weighted matching techniques [Frölich, 2004]. However, these techniques reduce the probability of one or a few matching variables measured on a very large scale dominating the matching procedure. In addition, trimming improves the efficiency of these approaches.

We carried out several variations of the matched pair analysis (e.g., z score matching), with none of these alternative formulations resulting in substantively different findings. The matching and statistical analysis strategies presented here were ultimately selected because they generated fewer problems (e.g., vulnerability to outliers) and took the greatest advantage of the available data. The rank matching approaches we use in section 3.5 are compared with z score approaches in Table 3.12.

Table 3.12: Error comparison for weighted z-score matching and rank matching

	Rank Error	Squared Error	Ratio of Squared Error to z-Score Squared Error (Untrimmed)	Ratio of Rank Error to z-Score Rank Error (Untrimmed)
Z score matching: full set of matches	97672	20791312	N/A	N/A
Z score matching: trimmed set of matches[a]	87054	13291904	64%	89%
Rank matching: full set of matches	92914	27268601	131%	95%
Rank matching: trimmed set of matches[a]	81056	23484917	113%	83%

Source: Author(s)

[a] In this study, trimming was used to eliminate the worst 10% of matches.

CHAPTER 4:
POST-CONSTRUCTION SUPPORT AND THE SUSTAINABILITY OF RURAL WATER PROJECTS IN GHANA[24]

Summary

This case study draws on data from 200 villages in Ghana's Volta and Brong Ahafo regions to examine what kind of post-construction support services villages solicit and receive, and whether unsolicited (supply-driven) post-construction assistance is positively associated with the technical sustainability of non-mechanized handpump systems. In Ghana, both "demand-driven" and "supply-driven" PCS systems exist, and both government and non-governmental actors are involved in support activities. In contrast to recent findings in the literature, but like the other two case studies in this volume, we find that most of the water systems we studied are in fact working. In the sample villages, borehole equipment breaks down often, but most water and sanitation committees in both Volta and Brong Ahafo effectively mobilize the resources needed to make minor repairs in a matter of a few days. Using regression analysis and nearest neighbor matching, we find that one form of post-construction support—additional technical training for village-based caretakers—is positively associated with technical sustainability.

4.1 Introduction: the rural water supply sector and post-construction support in Ghana

By 2001, about 62 percent of Ghana's rural population had access to improved water services, according to the World Health Organization-UNICEF Joint Monitoring Program for Water Supply and Sanitation.[25] Since 1995, the Ghanaian Community Water and Sanitation Agency (CWSA) has been responsible for coordinating and facilitating activities in the sector (Edig, Van Engel, and Laube 2002). As in many developing countries, various external donors provide much of the financing for capital investments in rural water supply projects.

CWSA's national strategy promotes a demand-driven planning approach that emphasizes participatory project design and implementation. The rural water supply projects are expected to include discussions with communities about relevant technology and management choices, and women's participation is valued and encouraged. Communities also make an upfront contribution to capital costs (5–10 percent).

Water and sanitation ("watsan") committees are formed in each project community. Project implementation is expected to include initial training for these committees along with special training on repair and maintenance for two village-based "caretakers" who are generally members of the watsan committee. Though district assemblies hold the water systems in trust for the communities, the watsan committees are responsible for managing the systems and for raising revenue from the communities to pay for operation, maintenance, and repairs.

Post-construction support

The watsan committees and caretakers have access to a well-developed, multi-faceted system of post-construction support. A central actor in this system is the district water and sanitation team

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[24] This chapter was written by Kristin Komives, Marc Jeuland, Bernard Akanbang, Rich Thorsten, Benedict Tuffuor, Wendy Wakeman, Eugene Larbi, and Dale Whittington. The authors would like to thank Rob Chase, Jennifer Sara, Vijayendra Rao, and Robert Roche for comments on the research project in general. All opinions expressed in the chapter are those of the authors.

[25] World Health Organization (WHO) and United Nations Children's Fund (UNICEF) *Joint Monitoring Program (JMP) for Water Supply and Sanitation database.* Available at JMP website <*http://www.wssinfo.org/en/welcome.html*> (accessed 26 September 2006).

(DWST), which consists of an engineer, a hygiene expert, and a community mobilizer who are seconded to the district government. DWST members are not supposed to repair the handpumps themselves, but rather to help the village watsan committees to obtain the support and training they need to run and repair the systems, resolve any management and water use conflicts that arise, and plan new capital projects. The DWSTs visit watsan committees on request, and help communities to find spare parts if asked to do so. They also visit some communities on their own initiative to check on conditions and organize training sessions on topics they consider relevant. The financial resources available to the DWSTs to carry out these functions are limited and vary across districts. How much attention a village receives from a DWST depends both on how proactive the village is in requesting assistance and on the resources and priorities of the district-level team.

Another important resource for watsan committees is the area mechanic living in the district. Area mechanics are private individuals who were originally trained during project implementation to do routine maintenance or repair work on boreholes at communities' request. They are often called upon to obtain and then install needed spare parts. Communities must pay for their services, and for spare parts, from revenues collected from households or money obtained in some other way. The DWSTs may help watsan committees link up with an area mechanic when major repairs are needed.

Area mechanics, caretakers, and watsan committee members obtain spare parts from a system that includes a central spare parts warehouse in Tema, Ghana, and three subnational warehouse outlets in the northern, middle, and southern zones of the country. The warehouses and outlets are needed to ensure the availability of pump parts for the four standard models of handpump that are used in Ghana.[26] Efforts are underway to have at least one spare parts outlet in each region.

The services provided by the area mechanics and the spare parts outlets are largely demand-driven forms of PCS, in the sense that communities receive them if they request or seek assistance. The work of the DWSTs is also largely demand-driven (responses to community requests), though these teams also provide some unrequested support.

In some parts of the Volta region, Ghana has an official PCS program that is not linked to demand for PCS services: Monitoring of Operations and Maintenance (MOM) is a program of quarterly visits to communities by district environmental health assistants (EHAs). During their visits, the EHAs do a technical assessment to determine how well the boreholes are functioning, review financial records, and check on payment practices. The records of their quarterly audits are compiled at the district level, in principle giving district-level officers a systematic picture of what is happening in the district. In 2002 and 2003, the Danish aid agency DANIDA funded MOM in the Volta region, but by 2004, after the responsibility for the program reverted to the district governments in Volta, only four districts had continued the MOM audits on a quarterly basis; other districts had reduced the frequency due to resource constraints.

Alongside the government-provided PCS system, less systematic forms of post-construction support are supplied by a myriad of sources. Some villages receive grants to fund repairs or new boreholes through members of Parliament, ethnic organizations, or private companies active in the villages. Others have enjoyed free handpump repairs provided by the Church of Latter Day Saints or other NGOs. Also, though contrary to PCS protocol in Ghana, DWST officials and area mechanics have sometimes repaired handpumps free of charge.

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[26] Nira, Afridev, Ghana-modified Indian Mark II, and French Vergnet.

To sum up, villages in Brong Ahafo and Volta have access to an official "demand-driven" PCS infrastructure of area mechanics, district water and sanitation teams, and spare parts networks. To make a repair through this system, they must find a way to contact a service provider and pay for the parts or services they need. The MOM program's primary purpose is to gather information, but it also provides Volta villages an extra avenue for obtaining advice and contacting service providers (it does not relieve them of the responsibility to pay for parts and services). Some villages in each region manage to obtain free repair services or a grant to cover their repair costs; much of the "free" assistance comes from private, religious, or non-governmental organizations.

Outline of study

In this study, we examine the correlation between technical sustainability and four forms of unsolicited post-construction support: post-construction technical training, regular visits by DWST members, free and unsolicited repairs or grants, and the MOM program. Section 4.2 describes the sample selection and data gathering, and Section 4.3 describes the socioeconomic characteristics of the sample villages, the performance of their water systems, and their experiences with post-construction support. Section 4.4 describes the analytical framework and methods used to investigate the relationship between PCS and water system sustainability; we use both logistic regression analysis and one-to-one matching to examine the relationship between unsolicited PCS and two dimensions of sustainability: technical performance and household satisfaction with the repair and maintenance of handpumps. Section 4.5 presents the results, and Section 4.6 concludes.

4.2 Sampling frame and data gathering

We selected a sample of 200 villages that represent the range of PCS services currently available in Ghana. In Volta, we selected sample villages from all the four districts (Ho, Jasikan, Kadjebi, and Nkwanta) that were receiving regular quarterly MOM audits and hence could be considered "treatment" villages. Brong Ahafo was chosen as the second region for the study because its conditions are similar to those in Volta in terms of water resources and the design of rural water supply programs. Villages in Brong Ahafo received systems through the World Bank-financed Community Water Supply Program I. This program used a demand-driven approach to project planning that was very similar to that of the Danida-funded program in Volta, but it did not supply unsolicited PCS; hence the Brong Ahafo villages could be considered as a "control" group. As in Volta, villages in Brong Ahafo did not have access to a spare parts warehouse within the region and showed variation in their distances from the urbanized regional capital. Using data from the 2001 census, we selected villages from the five Brong Ahafo districts (Asunafo, Dormaa, Kintampo, Tano, and Wenchi) whose district-level socioeconomic characteristics best matched those of the Volta districts in our sample.

Within the districts selected in Volta and Brong Ahafo, we restricted our sample frame to villages that had received no more than two deep boreholes with non-mechanized handpumps at least four years before our fieldwork began. These sample selection criteria yielded a potential sample frame of 97 villages in Volta and 120 villages in Brong Ahafo. All 97 Volta villages were selected, along with 103 of the 120 Brong Ahafo villages.

Various data collection exercises were conducted in each village, including 25 interviews with households chosen at random in each village (yielding a total sample of 5,000 households); interviews with the village water supply committee in each village; focus group discussions;

technical assessments of the handpumps; and observations of water collection at the handpumps. Fieldwork ran from late March to early May 2005. The research team typically spent an entire day in a village collecting data.

4.3 Profile of the villages and their water supply systems

The average village in the sample has a population of about 600,[27] has no electricity, and is located 11 km from a paved road and about 1.5 km. from a stream or river (Table 4.1). Most villagers report trusting their neighbors and leaders. Mean cash expenditure by households in the average village is US$68 per month. A fifth of the villages have access to a hand-dug well, stream, or river within 1 km of the village that has water during the entire dry season.

Although the sample villages in Brong Ahafo and Volta are similar in many respects, there are some differences between the two groups. Half the Volta villages are located on a paved road,

Table 4.1: Village characteristics: Brong Ahafo and Volta

	Total sample	**Brong Ahafo**	**Volta**
Median village population	605	742	360
Median time it would take adult to walk across village (in minutes, as reported by village leaders)	10	7	13
Mean distance to nearest post office (km)	13.9	13.6	14.2
Mean distance to nearest paved road (km)	11.3	17.2	5.0
Mean distance to nearest public telephone (km)	13.4	14.9	11.9
Mean distance to river or stream (km)	1.4	1.5	1.2
Mean % of households in village who say they trust their neighbors	75	75	75
Mean % of households in village who say they trust their leaders	77	74	80
Mean % of households in village with electricity, in villages that have electricity	45	34	49
% of villages without electricity	69	82	54
Mean HH monthly cash expenditure in village (US$)	68	81	54
Water system characteristics			
% of villages with only one borehole installed by project	50	56	43
Median population per installed handpump	442	583	307
% of villages with reliable alternative water source in dry season within 1 km of village	19	18	20

Source: Author(s)

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[27] The selected villages ranged in size from approximately 150 residents to 5,000 residents. The total population of the villages selected for the Brong Ahafo sample is about 75,000, and that of the selected Volta villages just over 100,000.

as opposed to only 15 percent of the villages in Brong Ahafo. More of the villages in Volta have electricity. On the other hand, villages in Brong Ahafo have a higher percentage of landowning households (62 percent versus 49 percent) and are richer, as measured by the mean reported monthly cash expenditure of households in the village.

Interviews confirmed that the project methodology used to install the water systems in both villages was similar on most counts. Households in almost all of the villages in both regions felt that they controlled decisions about the composition of the watsan committee and about the tariff adopted after construction. In a third of cases, participants in the women's focus groups stated that women had been actively encouraged to participate in preconstruction meetings. Villagers in Brong Ahafo, however, seem to have been more involved than villages in Volta in decisions about where to site boreholes and what technology to apply (roughly two-thirds of Brong Ahafo villages versus one-fifth of Volta villages were so involved). On the other hand, many more watsan committees in Volta recalled receiving instruction manuals for handpump operations and repair (60 percent in Volta versus 12 percent in Brong Ahafo).

The non-mechanized handpump systems in the villages studied were installed between four and eight years before the study took place, with an average of six years. Half the villages received one borehole with handpump through the Danida or World Bank-financed rural water supply program; the others received two. There were more users per handpump in Brong Ahafo than in Volta, and one day of observation at the most-used handpump in each village found an average of 328 users per day in Brong Ahafo and 162 per day in Volta. At the time of construction, watsan committees were formed in the villages and two caretakers were trained in each. At the time of our fieldwork, 90 percent of villages still had active committees (Komives et al. 2007), and 83 percent still had caretakers.

Technical sustainability and the functioning of water systems

Almost all of the study villages in both Volta (96 percent) and Brong Ahafo (96 percent) had experienced borehole breakdowns since their system was constructed. This in itself does not indicate project failure or neglect—it is simply a feature of the technology. But most handpumps in the sample were working at the time of the survey; only 12 percent of villages in Brong Ahafo and 8 percent in Volta were without a functional handpump or borehole.[28] To repair the last breakdown, households reported, it took an average of 18 days in Brong Ahafo and 22 days in Volta. On average, 87 percent of the households interviewed in each village reported being satisfied or very satisfied with the repair and maintenance of their handpumps (Table 4.2).

Virtually all households relied on the project handpumps for at least part of their water use: 96 percent of households in the average Volta village and 98 percent in the average Brong Ahafo village reported collecting at least some of their water from the project borehole. Mean reported per capita water use during the dry season for those households collecting water from the boreholes was about 28 liters in Brong Ahafo and 33 liters in Volta—figures that are very close to the average withdrawals we recorded by observing the use of the boreholes in each village. These levels of per capita water use are quite high for rural areas of Africa where people carry water from a source outside their home (Katui-Kafui 2002; Mu, Whittington, and Briscoe 1990;

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[28] We considered handpumps not to be working if they were completely broken down or unusable, if the handle was broken, if the handpump produced no water after 30 strokes, or if the borehole did not have water year-round.

Table 4.2: Water systems in the sample villages

	Total sample	Brong Ahafo	Volta
Description of the system			
Average years since project completion	6	6.2	5.8
% of villages with only one borehole installed by project	50	56	43
Median population per installed handpump	442	583	307
% of villages with reliable alternative water source in dry season within 1 km of village	19	18	20
Technical sustainability of the system			
Percent of villages where all project handpumps are working	89	88	92
% of villages that had ever experienced a breakdown	96	96	96
% villages with working systems that had a breakdown in last 6 months	57	58	55
Median days to repair the system last time it broke (reported by hhs)	20	18	22
Mean % of HHs reporting satisfaction with repair and maintenance service	87	84	89
Management structure			
% of villages where the committees regularly holds meetings with the community	72	75	70
% of villages where the committee members are elected	42	46	38
% of villages where the committee members are appointed	43	36	44
Mean % of watsan committee members who are women	41	41	41
% of villages with no caretaker	17	25	8

Source: Author(s)

White, G, Bradley and White, A. 1972), and show that the borehole projects have been supplying relatively large quantities of water for household use.

The borehole projects have not, however, eliminated all use of unprotected water sources for drinking and cooking. About half of the sample households in both regions reported using a river, stream, or other surface water source during the dry season, and a quarter reported that they used that water for drinking (20 percent in Brong Ahafo and 32 percent in Volta). Rainwater collection was also very common (roughly 75 percent of households).

The rural water supply model in Ghana expects watsan committees to collect money from households to fund repairs. However, the survey responses make clear that many watsan committees did not have a regular revenue collection system in place and that many households were not paying even where such a system existed. Only 71 percent of the households who used borehole water reported paying for it. Thirteen percent of the watsan committees interviewed said they were not collecting water revenues from households. Another 16 percent collected money only when needed to make a repair. In villages with pay-as-you-fetch systems (54 percent of Volta villages and 24 percent in Brong Ahafo), the average price was about US$0.01 per jerry can. Among households who were paying for water, the average reported monthly expenditure for water was US$0.99 in Volta and US$0.89 in Brong Ahafo. Sixty-five percent of the watsan committees interviewed said that they collected enough money from households to pay for minor repairs, but only 30 percent said that they could pay for major repairs with this revenue.

Post-construction support

Roughly half the watsan committees in the sample indicated that it was "easy" or "very easy" to get technical assistance for a problem that they could not fix themselves. Usually, this assistance came from area mechanics at villages' request. Three quarters of the sample villages had called on an area mechanic at least once, and 15 percent had asked the area mechanic to help obtain a spare part. On average, area mechanics would come within four to five days after they were called, and 90 percent of the watsan committees felt that the mechanics were skilled enough to resolve the technical problems that the village could not resolve on its own. About 20 percent of the watsan committees said that it would be difficult or very difficult to get an area mechanic to visit their village.

Roughly 70 percent of villages (73 percent in Brong Ahafo and 65 percent in Volta) reported receiving at least one visit from the DWST, and 20 percent of the watsan committees said that the DWST members visited regularly—at least once a year but in a few cases as often as once a month. There was no significant difference in the frequency of DWST visits in the two regions, and the watsan committees provided a similar assessment of the responsiveness of DWSTs to their requests (a third said the DWSTs always followed up). The DWSTs had been providing technical training, financial training, and/or management training during the post-construction period, each in 20 to 30 percent of villages.

In Volta, other sources such as MOM's environmental health assistants and NGOs had also provided post-construction training, such that far fewer Volta villages reported receiving no training in the post-construction period (17 percent of the Volta watsan committees vs. 60 percent in Brong Ahafo). But very few watsan committees in Volta mentioned help with repairs or technical aspects of borehole management as a benefit of the MOM program, indicating that MOM's involvement in technical issues had been largely limited to gathering information for district officials about the technical status of each borehole.

On financial and administrative matters, villages in Volta were much more likely than villagers in Brong Ahafo to report receiving assistance—as one would expect, given that only Volta villages are in the MOM program. When asked what they found most useful about the MOM audits, watsan committees in Volta pointed to help with general management, financial records and tariffs, hygiene education, and attention to borehole cleanliness.

Thirty percent of the villages in the sample (35 percent in Volta and 25 percent in Brong Ahafo) had received some form of financial assistance (a grant or a free repair) to supplement revenues they had collected internally. Thirty-three percent of villages in Volta and 13 percent in Brong Ahafo had received free repair or maintenance services on at least one occasion since 2001. In most of the cases, the village had not directly requested this assistance. NGOs or religious organizations provided the free help in half of the Volta cases. The Church of Latter Day Saints has been very active in this region, and much of their support has involved major rehabilitation of handpumps. The rest of the Volta cases and most of those in Brong Ahafo involved free repair or maintenance assistance from the DWST or, in a few cases, from area mechanics.

In short, most watsan committees had received multiple forms of demand-driven and supply-driven PCS services. Paid technical support from area mechanics was generally the result of watsan initiatives. Unpaid technical support visits from the DWSTs were sometimes requested, but more often unsolicited. In Brong Ahafo, help with spare parts was usually in response to requests, but in Volta it more often arrived unsolicited. Almost all the watsan committees reported that assistance with financial and administrative matters was supply-driven, and not requested by the villages, but this form of support was largely confined to Volta and provided through the MOM program.

Table 4.3 looks at the packages of unsolicited, technically oriented PCS that villages received in the post-construction period. Forty percent of the villages in each region received no technically oriented unsolicited PCS; half of those villages are in Volta, and participated in the MOM audit program. Roughly another 40 percent of the villages in each region received one form of unsolicited support—whether technical training (24 percent), visits from the DWSTs at least once a year (10 percent), or a free repair or grant for repairs to existing boreholes (8 percent). The remaining 20 percent received either two or three of these forms of support. The frequency of these different unsolicited PCS packages is very similar across the two regions.

This variety of arrangements for PCS makes it a challenge to isolate the effect of any one form of support.

Associations between post-construction support and technical performance

Across the whole sample, villages that received some form of unsolicited technically oriented PCS (technical training in the post-construction period, regular DWST visits, a free repair, or a grant to repair an existing borehole) were significantly more likely to have working borehole systems than were villages that received no such support. More households in the supported villages were also satisfied with the maintenance and repair service in the village (Table 4.4).

Table 4.3: Percent of villages receiving different packages of unsolicited PCS support in post-construction period

Package of unsolicited PCS	Full sample	Brong Ahafo	Volta
None	41.2	42.2	40.2
Just technical training	23.6	26.5	20.6
Just regular DWST visits	10	8.8	11.3
Just free repair or grant	8	3.9	12.4
Technical training + regular DWST visits	6.5	9.8	3.1
Technical training + free repair or grant	4.5	4.9	4.2
Regular DWST visits + free repair or grant	3	2	4.1
All three forms	3	2	4.1

Source: Author(s)

Table 4.4: Technical sustainability and post-construction support packages

Villages that received…	***Compared to…***	***Are all project boreholes in village less likely to be working? (Pearson chi2)***	***Is the % of hhs in village satisfied with repair and maintenance service significantly lower? (One-tail t-test)***
No technically-oriented PCS	All others	4.37**	1.69**
No post-construction technical training or regular DWST visits	All others	2.85*	2.79***

Source: Author(s)

Note: Asterisks denote $0.05 < p \leq 0.1$. Double asterisks denote $0.01 < p \leq 0.05$. Triple asterisks denote $p \leq 0.01$.

When villages that received technical training or regular DWST visits (that is, support through the official PCS system) are compared to all other villages, it also appears that unsolicited post-construction support improves technical sustainability and satisfaction. However, many other important differences between the villages could be masking the true effect of PCS packages on sustainability and satisfaction. To try to isolate the effects of different types of unsolicited PCS, we turn to the regression and matching techniques described below.

4.4 Analytical framework and methods

We examine the relationship between unsolicited PCS and two dimensions of the technical sustainability of the water systems: (1) technical performance—whether the boreholes and handpumps were functioning at the time of our visit—and (2) household satisfaction with handpump repair and maintenance. Our measure of technical performance is a dichotomous variable that measures whether or not all project handpumps were working when the research team visited the village. Household satisfaction is measured as the percent of interviewed households in the village who report being satisfied with handpump repair and maintenance. We use logistic regression analysis and one-to-one village matching to test for an association between various forms of PCS and these indicators of technical sustainability.

As the basis for the logistic regression analysis, we hypothesize that sustainability (S) at the village level is a function of project, village, and household-level variables:

$S_i = f(\text{Project}_i, \text{PCS}_i, \text{System}_i, \text{Watsan}\ i, \text{Village}_i, \text{HH}_i)$, where:

S_i = Technical sustainability of the water system in the ith village;

Project_i = Village level pre-construction factors (e.g. community involvement in project planning);

PCS_i = Post-construction support;

System*i* = Village-level water system characteristics (e.g. years since pump installation, number of project boreholes, availability of an alternative water source during the dry season);

Watsan *i* = Characteristics of the village-level management structure (percent of committee members who are women, presence of village-level caretakers);

Village*i* = Village characteristics (population per handpump, ethnic homogeneity of the population, distance from area mechanic); and

HH*i* = aggregate measures of village household or resident characteristics (median household expenditure level, percent of households who say they trust their leaders, percent of households with electricity).

We also use selected variables from this model to implement nearest-neighbor matching, in which we pair villages with various PCS treatments to control villages that had received either (1) no unsolicited PCS or (2) villages that had not received the treatment variable of interest but may have received another type of PCS. Many of the newest matching techniques in the literature combine several aspects of distance matching, caliper matching, interval matching, trimming the support region, and difference-in-difference matching, and it is becoming increasingly difficult to choose the best approach (Smith and Todd 2005). We developed a linear programming (LP) model for creating “nearest-neighbor” matches that addresses some of the weaknesses of strict distance matching. The same approach was used in the Bolivia case study (see Chapter 3 and its appendix). Instead of minimizing the absolute or squared differences over a set of village characteristics, our model requires exact matches on a subset of key variables (region, number of boreholes in the village, and the availability of an alternative water source in the dry season). It then assigns ranks to the absolute differences on other variables between village pairs, and minimizes the sum of these ranks across the set of matching characteristics (see Appendix 3.1).

This assignment strategy reduces the probability of creating matches between villages that are quite different in one particular characteristic but similar in all others (thus having relatively low absolute differences). This “nearness” weighting also removes the problems of scaling that can occur when the matching characteristics are measured by very different metrics.

To test whether the number of variables used to create the matches would affect the results of the analysis, three different groups of matching variables are used to find the nearest-neighbor matches for different treatment groups (Table 4.5). Once the matched pairs were created, a chi-squared test and one-sided Fisher’s exact test were used to examine whether there is a significant difference between treatment and control villages.

4.5 Results: influences on sustainability

Results from regression analysis

Table 4.6 reports the results of the logistics regression model and regression model that we used to examine the association between PCS and the two indicators of technical sustainability, as well as the summary statistics for variables used in the models. The signs of the non-PCS variables in the model are generally as expected. We tested reduced forms of the models, and they did not change the conclusions.

Table 4.5: Variables used to produce matchings

Group 1	**Group 2**	**Group 3**
• Region • Number of handpumps • Alternative dry season water source within 1k of village • Distance of area mechanic • Population in 2001	• Group 1 variables + • Measure of ethnic homogeneity • Percent of population with electricity • Median household expenditure in 2004	• Group 1 variables + • Group 2 variables + • Number of caretakers in village in 2001 • Village had regular payment system in place after construction

Source: Author(s)

Table 4.6: Regression results

Variable	**Variable definition**	**Mean (s.d)**	**Logistic regression β (odds ratio)**	**OLS regression β**
Dependent variable			All project boreholes in the village are working	% of villagers satisfied with repair and maintenance service
Number of handpumps	1=village received only one hand pump	0.49 (0.50)	1.531** (4.62)	–0.003
System age	Number of years since handpumps were installed	6.01 (0.76)	–0.118 (0.89)	0.005
Population	Log of village population	6.60 (0.95)	–1.115*** (0.33)	0.005
Reliable unprotected alternative source	Village has unprotected source that always has water during the dry season within 1 km of the village	0.19 (0.39)	–1.474* (0.23)	–0.043
Remoteness	Distance in km to area mechanic	19.55 (18.09)	0.024 (1.02)	–0.000
Electricity	1= village has electricity	0.31 (0.46)	2.911** (18.38)	0.012
Ethnic homogeneity	Percent of the population in the village in the largest ethnic group	74.14 (22.51)	0.032** (1.03)	0.000
Trust of leaders	Percent of hhs interviewed who say they trust their village leaders	77.37 (15.58)	0.044* (1.04)	0.002***

(*continued on next page*)

Table 4.6: Regression results

Variable	Variable definition	Mean (s.d)	Logistic regression β (odds ratio)	OLS regression β
Average cash expenditure	Log of median household cash expenditure in village	3.99 (0.32)	1.249 (3.48)	–0.074*
Caretakers	Number of caretakers in the village	1.26 (0.82)	0.477 (1.61)	0.033**
Women on watsan	% of watsan members who are women	40.75 (15.13)	0.024 (1.02)	–0.000
Technical training	1= During the post-construction period, village caretaker has received technical training	0.38 (0.49)	1.511* (4.52)	0.047**
Regular DWST visits	1=Watsan receives regular visits from DWST, at least once a year	0.23 (0.42)	1.883** (6.57)	0.062**
Free repair	1=Village handpump has received at least one unsolicited free handpump repair	0.15 (0.39)	–0.171 (0.84)	–0.073**
Grant	1= Village received at least one unsolicited grant to help with handpump repair	0.06 (0.25)	3.234** (25.37)	0.021
Volta/MOM	1= Village is in Volta	0.49 (0.50)	0.068 (1.07)	0.020
Constant			–3.587	0.834***
Observations			199	199
(Pseudo) R-squared			0.38	0.25

Source: Author(s)

Note: Asterisks denote $0.05 < p \leq 0.1$. Double asterisks denote $0.01 < p \leq 0.05$. Triple asterisks denote $p \leq 0.01$.

Looking at how village characteristics may affect technical sustainability, the results from the first model show, first, that, if a village has only one borehole, the borehole is more likely to be working. We interpret this to mean that the watsan committee makes more effort (and is under more community pressure) to keep a handpump system working when failure would leave the community without any improved water supply. Population size is negatively associated with technical sustainability. This could mean either that more intensive use of the handpumps leads to a need for more difficult or expensive repairs or that households value the handpumps less when they share them with more other households (and thus put less pressure on the watsan committees to fix them). Villages that have a reliable unimproved water source within one kilometer of the village are *less* likely to have functioning handpumps. We understand this to mean that households put less pressure on watsan committees to fix broken pumps when they have an alternative source nearby (World Bank Water Demand Research Team 1993).

The model results also show that trust in leaders, ethnic homogeneity, and electricity coverage (a measure of wealth) are all positively associated with technical sustainability. Interestingly, system age, distance from the nearest area mechanic, and having a caretaker in the village are not significant. This is noteworthy because it is consistent with the idea that the post-construction support system is working to neutralize what one would expect to be the negative effects on sustainability of system age, remoteness, and problems with the village-level management structure.[29]

Turning to the PCS variables in the model, post-construction technical training for village caretakers is positively associated with technical sustainability. Thus, it is not so much having a caretaker, but rather having a *recently trained* caretaker, that would seem to help keep systems running in these villages. Receiving regular visits from DWST members (at least once a year) is also positively associated with having functioning systems. Grants, too, are positively associated with technical sustainability. Free repairs, on the other hand, though insignificant in the model, have a negative sign, suggesting that an unsolicited free repair works against technical sustainability in the long run. The MOM/Volta variable has an insignificant effect on sustainability. Perhaps this is because this dummy variable picks up differences between Volta and Brong Ahafo for which we have not been able to control in the model. Nonetheless, this finding also raises questions about whether the MOM audit program has any positive effect on technical sustainability in a context like these Volta communities, which have access to many other forms of PCS. In interviews, village watsan committees did not readily recognize that they received any help with technical issues through the MOM program. Assistance with financial, managerial, and hygiene matters may have some indirect effect on technical sustainability, but not one that shows up in this model.

The model of household satisfaction with repair and maintenance of the handpumps does not have strong explanatory power, but it yields conclusions about unsolicited PCS that are similar to those of the logistic regression model. In the household satisfaction model, the Volta variable has no significant effect; technical training and regular DWST visits are both positively associated with satisfaction; and grants have a positive, but not significant, effect on sustainability. Receiving a free repair has a significant negative effect, possibly because villages that were in a position to receive unsolicited free repairs were those that could not maintain and repair their systems on their own. Turning to the other variables in the household satisfaction model, the number of caretakers and villagers' trust in their leadership are both positively associated with household satisfaction. Cash expenditure has a significant and negative effect on satisfaction, suggesting that wealthier villages are less satisfied and possibly more demanding.

In sum, both models suggest that villages where caretakers have received repeat technical training in the post-construction period and/or where DWSTs made regular visits are likely to have better technical performance. Grants are positively associated with having working boreholes, but not with household satisfaction with the repair and maintenance service, and free repairs appear to even have a negative effect on system performance.

The PCS variables in these regression models identify villages that have received each type of PCS, but many will have also received other types of support as well. Next we use the matching

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[29] In the case of system age, the narrow range of variation in this variable (four to eight years) may also explain its insignificance in the model.

technique described earlier to compare the technical sustainability of villages that received particular packages of unsolicited PCS. We focus on examining technical training and DWST visits, as these are the variables that were significant and positive in both regression models.

Results from matching

Table 4.7 presents the results of our comparison of matched pairs of villages. The results for different sets of matched pairs are presented: villages matched on a basic set of five variables, and villages matched on an extended set of 10 variables. We also matched on eight variables, but as the results were consistent with those presented here, they are not included in the table.

We first compare villages that received only technical training or only regular DWST visits to villages that received no technically-oriented unsolicited PCS at all, or a PCS package that did not include the treatment of interest. Next, we compare villages that received PCS packages *including* technical training or regular DWST visits to villages that did not receive those treatments.

Table 4.7: Post-construction support and technical sustainability: comparison of matched pairs

Unsolicited, technically-oriented PCS received by....		**Match on basic set of variables**	**Match on extended set of variables**
Treatment villages	**Control villages[1]**	**X^2 (# of pairs)**	**X^2 (# of pairs)**
Only technical training	None	5.28**++ (35)	3.17*+ (36)
	None, or package w/o technical training	6.13**++ (46)	4.04**++ (46)
Only regular DWST visits	None	1.04 (13)	2.15 (14)
	None, or package w/o regular DWST visits	0.36 (20)	0.55 (20)
Technical training, or package including technical training	None	4.70**++ (54)	2.96*+ (53)
	None, or package w/o technical training	2.96*+ (73)	1.66 (73)
Regular DWST visits, or package including regular DWST visits	None	3.15* (31)	6.62***++ (32)
	None, or package w/o regular DWST visits	0.55 (45)	1.11 (45)

Source: Author(s)

X^2: *.05 $< p <$ .10 **.01 $< p <$ .05 ***$p < .01$

Fisher's exact 1-sided: + .05 $< p <$ .10 ++ .01 $< p <$ .05 +++ $p < .01$

(1) If closest neighbor had received unsolicited PCS, and second closest neighbour was a high quality match but had not received unsolicited PCS, second closest neighbour was used as the control.

The results present strong support for the idea that villages that received post-construction technical training (either alone or in combination with other forms of unsolicited PCS) are more likely to have working handpump systems than other villages. This is true regardless of whether the other villages received no technically-oriented PCS at all or received a package that did not include training.

Unlike post-construction training, regular DWST visits on their own do not appear from the matching results to increase the likelihood of having working handpump systems: villages that received only regular DWST visits do not perform better than villages that received no technically-oriented PCS at all or a package that did not include DWST visits.

4.6 Discussion and Conclusions

From the cross-sectional analysis, it is clear that most rural water supply systems in our sample were working, whether or not they had received any form of unsolicited PCS. To be sure, handpumps were breaking down, but village watsan committees and caretakers were managing to fix problems or have them fixed with outside help. Watsan committees were taking advantage of the demand-driven PCS that is available in Ghana to find parts and fix their systems. This is good news and provides evidence that communities can do a lot to keep systems running with the help of some basic forms of demand-driven PCS (such as area mechanics and spare parts warehouses).

Nonetheless, our results also suggest that at least one type of unsolicited, supply-driven PCS increases the likelihood that systems will be working four to eight years after construction. Across the whole sample, villages were more likely to have working systems if they had received some form of unsolicited technically oriented PCS than if they had received no such assistance. Households in villages that had received this unsolicited assistance were also more likely to be satisfied with the handpump repair and maintenance in their villages.

The type of unsolicited PCS that appears most promising for improving technical sustainability is post-construction technical training. This form of assistance helps maintain the local capacity to make repairs and thus reinforces the community-based repair and maintenance model. There is also some evidence that regular (though not necessarily frequent) visits from DWST members help improve sustainability in combination with other kinds of PCS, but not on their own.

We have not attempted to determine whether the benefits of these PCS services exceed the costs of providing them. This is an important question for future research, because not all forms of post-construction support that improve sustainability will necessarily be cost effective. It should be kept in mind that performance was good even in villages that had not received unsolicited PCS: even in villages that had received no unsolicited PCS at all, 84 percent of the handpumps were working, and more than 80 percent of the households said they were satisfied with the repair and maintenance service.

This case study also raises important questions about the usefulness of the MOM quarterly audit program in promoting technical sustainability. The MOM program seeks to help watsan committees and DWSTs by collecting information about hygiene and cleanliness, financial and managerial issues, and technical sustainability in rural water supply systems. We did not investigate whether the MOM program improved hygiene, water use habits, or the cleanliness of the handpump sites, all of which would be expected benefits of regular visits by environmental health assistants. On the financial, managerial, and technical fronts, we hypothesized that the regular contact with EHAs and attention to these issues would provide an incentive for watsan committees to make improvements in these areas. If financial and managerial improvements mean greater and more regular revenue collection, this could in turn improve the financial capacity of watsan committees to carry out repairs when needed. Our regression results show no evidence that MOM (measured through a regional dummy variable) is positively associated with improved technical sustainability, but we are cautious about this finding, for two reasons. The first is that we had difficulties isolating the effect of MOM in our model from regional effects of being in Volta, since every village in the Volta region sample received this form of assistance. Second, evidence suggests that MOM may be carried out quite differently in different districts, by different EHAs. For example, only some of the watsan committees in the MOM program perceived that they had received assistance with financial or managerial issues. Still, given that we also failed to find that regular DWST visits *on their own* improve technical performance, this study raises doubts about whether unsolicited on-site visits by professionals is a necessary or cost-effective component of a PCS system, at least in a context like Ghana where watsans can access other forms of PCS when needed. The less intensive approach of caretaker retraining shows more promise in this case.

In future research, it would be interesting to evaluate whether the effect of a MOM-like program would be more significant in settings outside Ghana where fewer PCS resources are available. Another useful avenue of study would be to examine exactly how the environmental health assistants and district water and sanitation teams apply the information gathered through MOM. If this information is being used to decide which villages need retraining on technical matters or more frequent visits by DWST members, for example, it might be augmenting the impact of these other forms of unsolicited assistance. We found no conclusive evidence to suggest that training or DWST visits have a different effect on sustainability in the MOM or non-MOM regions, but it is interesting to note that all villages in Volta that received regular DWST visits had working systems at the time of the study visit. More investigation of the relationship between MOM and other forms of PCS is warranted.

We found no evidence that relieving watsan committees of their responsibilities through the provision of free repairs is positively associated with technical sustainability. While free repairs may provide villages with welcome short-term fixes, they are not associated with improved sustainability over the medium term.

How one chooses to help villages where the community management model has broken down may make a difference. In contrast to free repairs, unsolicited grants to fix broken systems are positively associated with having working systems (though not with household satisfaction) in our models. Thus, helping with finances but leaving villages the responsibility to negotiate and manage repairs might be better than taking over responsibility for the repair itself. Only 19 villages in our sample received grants (solicited or unsolicited), so this hypothesis deserves further study in future work. Nonetheless, the findings on free repairs and grants suggest that NGOs and other organizations that help villages to repair their systems outside the confines of the formal demand-driven PCS system should think carefully about their choice of intervention strategy, and consider how their work fits into Ghana’s PCS framework.

PART 3: SYNTHESIS

CHAPTER 5:
CONCLUSIONS AND LESSONS LEARNED[30]

This final chapter summarizes our findings about the status of rural water projects and the factors associated with their success, as well as our principal conclusions about the effects of post-construction support services on system performance and what they imply for decision-making about the maintenance and expansion of rural water supply systems.

5.1. Overview of findings

Communities were involved in pre-construction planning and helped with capital costs

The results of all three country case studies show that several of the desired preconstruction elements of the demand-driven, community management model were implemented in villages both with and without post-construction support. As noted in Chapter 1, these elements are: (1) involving households in the choice of technology and of institutional and governance arrangements; (2) taking account of women's views in decision-making; and (3) requiring households to pay all of the operation and maintenance costs of providing water services and at least some of the capital costs.

Our interviews showed that community members in all three countries felt that they had been involved in the pre-construction planning of their water systems. In all three countries, more than 90 percent of the focus groups that were held with village leaders and/or women reported that the community had been involved in tariff design. In about two-thirds of the villages in Bolivia and Peru (vs. 42 percent in Ghana), people felt they had been involved in the choice of technology. In just under half the villages in all three countries, people felt they had contributed to the decision on the location of the proposed infrastructure (on the location of water distribution lines in Peru and Bolivia, and of handpumps in Ghana).

In all three countries, communities contributed 5–10 percent of the capital costs of the project, but in many cases labor and/or land contributions were allowed to substitute for cash.

Community water supply projects are still working

Based on our reading of the literature (Edig, Van Engle, and Laube 2002; Engel, Iskandarani, and Useche 2003) and discussions with sector professionals familiar with the situation in all three countries, we expected to find a substantial minority—or perhaps even a majority—of the water systems in the villages in our sample to be performing poorly or broken down. This was not the case. In all three countries, in villages both with and without post-construction support, the rural water supply projects were working.

As shown in Table 5.1, all the piped systems studied in Peru, and all but one of those studied in Bolivia, were functioning at the time of our field visit. Among the households in our sample in Peru and Bolivia, 93 percent or more had operational taps at the time of our field visit. In 55 percent

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[30] This chapter was written by Dale Whittington, Jennifer Davis, Kristin Komives, Heather Lukacs, Linda Prokopy, Richard Thorsten, Wendy Wakeman, and Alexander Bakalian. We appreciate the helpful comments of Rob Chase, Vijayendra Rao, Jennifer Sara, Robert Roche, Donald T. Lauria, and Marc Jeuland.

Table 5.1: Profile of village water systems and management practices

	Bolivia	Peru	Ghana
Description of the system			
Average years since project completion	7	7	6
Percent of villages - private connections only	73 %	100 %	0 %
Percent of villages public taps only	4 %	0 %	100 %
Percent of villages private connections and public taps	23 %	0 %	0 %
Status of the system			
Percent of households with functioning taps	95 %	95 %	N/A
Percent of villages with all taps functioning	54 %	74 %	N/A
Percent of villages where all project handpumps are working[a]	n/a	n/a	89 %
Percent of villages with functioning systems that had reported a breakdown over last six months	55 %	55 %	57 %
Average days to repair the system (for villages that had experienced a breakdown)	1–2	5	18
Management structure			
Percent of villages where the committees regularly holds meetings with the community	86 %	81 %	72 %
Percent of villages where the committee members are elected	95 %	63 %	42 %
Percent of villages where the committee members are appointed	3 %	15 %	43 %
Median number of women in the committee	0	0	3
Percent of villages with no caretaker/operator	3 %	2 %	18 %
Percent of villages with paid caretaker/operator (in villages with a caretaker)	70 %	57 %	1 %
Cost recovery			
Cost recovery mechanisms			
Pay-by-the bucket or volumetric tariff	2 %	0 %	39 %
Fixed monthly fee	89 %	82 %	54 %
Fees vary by HH size	0 %	0 %	7 %
Irregular collections	0 %	7 %	16 %
No revenue collection	9 %	11 %	13 %
Percent of HHs in full sample who use the system that reported paying for water	87 %	77 %	71 %
Median monthly expenditure for water reported among HHs that pay for water (US$)	$0.55	$0.30	$0.16
Percent of committees reporting that HH collections cover operating costs	n/a	50 %	51 %
Percent of committees reporting that HH collections cover minor repairs	n/a	80 %	65 %
Percent of committees reporting that HH collections cover major repairs	n/a	12 %	30 %

Source: Author(s)

[a] 88 percent of the systems in Bolivia were gravity only; the others used pumps.

n/a: not applicable.

of the communities in Bolivia and 76 percent in Peru, 100 percent of the household taps were operational. In 90 percent of the villages in Ghana, all project boreholes were still working.

The fact that most systems were still functional an average of seven years after implementation is very good news for the rural water sector. The demand-driven, community management model seems to be working, at least in the medium term. Not only were the rural water systems producing water (i.e., not broken down), but almost all the households in these communities were obtaining at least some of their water from the systems. In Bolivia, 100 percent of the households who were interviewed reported using water from the improved water system; in Ghana, 97 percent; and in Peru, 95 percent. In Ghana, our estimates of the amount of water that households collected from boreholes ranged from 34 liters per day in Volta to 24 liters per day in Brong Ahafo. These levels of per capita water use are quite high for rural areas of Africa where people carry water from a source outside their home (Katui-Kafui 2002; Mu, Whittington, and Briscoe 1990; White, G, Bradley and White, A. 1972), and indicate that these borehole projects have succeeded in supplying relatively large quantities of water for household use.

In all three countries, the vast majority of village water committees (VWCs) were functioning as planned. They held regular meetings. Many of the VWC members were elected, and, in Ghana, many of them were women (Table 5.1).[31] In Bolivia and Peru, every community had a system operator who was responsible for operating and maintaining the water system. In Ghana, 82 percent of the communities still had a caretaker for the handpump(s). The systems in all three countries did occasionally break down, but in the majority of cases the VWCs had been able to arrange for repairs. Most of the sample villages in all three countries reported one or more breakdowns in the last six months, but in Bolivia, breakdowns were typically fixed in one to two days, in Peru in five days, and in Ghana in 18 days.[32]

In Ghana, most villages in the sample had functioning VWCs: only 3 percent of the committees in the study villages in Volta and 7 percent in Brong Ahafo had been disbanded or relieved of their duties, and another 5 percent of the committees were inactive or dormant. In some cases the committee had stopped work due to conflicts with the community or village leaders (usually over revenue collection, the use of collected revenues, or unsuccessful repairs). In others, the committee was dormant because it had “no work to do” (the borehole had either not broken down or had not functioned in a long time). In a few villages, another village-level institution had assumed the responsibility for the water system.

Villages use post-construction support

Despite the problems that many communities had in charging households for water services, most of the communities in all three countries were managing to keep their improved water systems functioning. Even communities that were not collecting enough revenues to pay for operation and maintenance costs were finding the resources needed to fix their systems when they broke down. Especially in Ghana, many of these resources came from outside the community (Table 5.2).

Communities were making use of a wide variety of government- and NGO-provided PCS services to keep their systems working. Some of the services were provided at their own request (“solicited

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[31] This does not necessarily mean that the women were active committee members (see evidence from India in Prokopy 2004).

[32] The main reason why repairs take longer in Ghana is that parts for boreholes must be obtained from outside the villages. In Bolivia and Peru, many repairs can be made with parts that communities have on hand.

Table 5.2: Profile of post-construction support activities

	Ghana	***Peru***	***Bolivia***
Percent of villages that received …. after completion of project construction …			
Visits from external organization(s) to assist with maintenance or repairs	52	14	22
Visits from external organization(s) to assist with accounting, tariffs, etc.	33	6	13
Technical training for the system operator	34	49	41
Free repairs	21	n/a	n/a
Written manuals or other materials	37	25	30
Help with finding or receiving spare parts	45	7	11
Grants from outside sources for repairs, new construction, system rehabilitation, capacity expansion, or other assistance	16	3	8
Percent of households visited by external agencies to discuss use of water system, etc.	30	25	n/a

Source: Author(s)

PCS") and others arrived on the initiative of government or NGO or church organizations ("supply-driven PCS").

Nearly half the communities in all three countries had received additional training for their water system operators or caretakers since construction. Some villages had received help with non-technical matters such as billing or disputes over water sources. When water systems broke down, system operators sought out spare parts and, if necessary, outside technical expertise to make repairs. Few VWCs kept sufficient cash on hand to pay for major repairs. Nonetheless, they seemed able to find enough funds for repairs, whether through one-time levies on villagers, grants from outsiders, or receipts of free parts or repair services. In some cases, the caretakers or VWCs turned to intermediaries to help identify and obtain the needed resources. In Ghana, for example, the district water and sanitation teams (DWSTs) and the environmental health assistants involved in the MOM program (an intensive supply-driven program of post-construction support that covers parts of the Volta region) helped communities to find technical assistance and spare parts. But other actors helped as well. One of the striking findings from our field activities in all three countries was the pervasive presence of NGOs and church organizations in post-construction support activities.

Many NGOs were providing both supply-driven *and* demand-driven post-construction support. In Bolivia, NGOs such as Plan International and CARE have taken on increasingly programmatic roles in the rural water sector in the sample villages as the role of government has diminished, and in recent years they have largely assumed responsibility for PCS. In Peru, the "prime contractor" NGO (SANBASUR) helped communities fill the gap between the revenues raised and funds needed for repairs by putting such communities in touch with partner NGOs or with municipal governments that could provide financial and other assistance. In Ghana, fully 16 percent of the sample villages had received grants for repairs and/or major rehabilitation from outside sources such as the Church of the Latter Day Saints (Table 5.2). The Mormons and perhaps other NGOs appear to have worked with the DWSTs to identify villages that were experiencing problems and then to help finance the repairs. The DWSTs not only lack funds to proactively monitor conditions in villages, but also are instructed by policy guidelines not to make or fund repairs themselves.

Consumer satisfaction is high

Given that the water systems were generally working and that communities were able to make repairs, levels of household satisfaction were very high in most villages in all three countries. On average, in Bolivia 83 percent of households in each village reported being “satisfied” or “very satisfied” with their system’s operation and maintenance regime, and 78 percent were “satisfied” or “very satisfied” with the performance of their VWC. In Peru, 61 percent of the households reported that they were satisfied overall with their improved water system. In Ghana, 88 percent of the households reported they were satisfied with the repair and maintenance services of the water system, and more than 80 percent of the women’s focus groups said they were satisfied with the system.[33]

But households are still using unprotected water sources

There are also some troubling findings. Although almost all households reported using the new water system, for some households this was not their only water source. In Ghana, 38 percent of households reported they were still using water from unprotected sources (e.g., springs, river, open wells) for drinking and/or cooking. The percentages were lower in Peru (21 percent) and Bolivia (23 percent), but still worrisome. We do not have information on the health consequences for the people in our sample villages who were still using traditional water sources, but we speculate that until households obtain their drinking and cooking water exclusively from improved sources, the health benefits of the investments in improved sources will not be fully realized, and any prospects for breaking out of a rural “poverty trap” in this way will be reduced.

Households pay little for improved services

Another worrisome finding is that the finances of many village water committees in the sample were in poor shape, because households were paying very little for the improved water services. These rural water supply programs were not designed for communities to recover the capital costs of construction or to provide for capital replacement or expansion. The cost-recovery objective was simply to collect enough revenues from users on an ongoing basis to pay operation and maintenance costs. However, a substantial minority of villages in our study were not achieving even this modest objective.

In both Bolivia and Peru, almost all villages were charging households a very modest fixed monthly fee for service. Most households reported paying for water (87 percent of households in Bolivia and 77 percent in Peru) but their median monthly expenditures were only US$0.25 and US$0.66 respectively. In Bolivia, not only were the monthly charges low, but 27 percent of the communities had actually lowered their tariffs since operation began. In Peru, we estimate that slightly fewer than half of the communities were recovering their operating costs.

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[33] Dissatisfaction in Ghana was primarily concentrated in villages where the handpumps were no longer working or had always had problems (e.g., with salty water or low pressure in the dry season).

In Ghana, 13 percent of the VWCs interviewed said that they were not collecting any money from households. When we asked households (in contrast to VWC members), we found that in 23 percent of the villages none of the interviewed households was paying for water. Only 71 percent of the villages in Ghana had any regular payment system in place for households (either pay-by-the bucket or a fixed monthly charge, as contrasted with an irregular system like collecting money from households when funds are needed for repairs). In villages that used fixed monthly fees, the most common rates were US$0.11 and US$0.22 per month. In villages using pay-by-the-bucket, the most common charges per 20-liter container were US$0.01 or less.

Among the VWCs in Ghana that did collect revenue from households, those in Volta reported collecting an average total of US$169 annually (versus US$173 in Brong Ahafo). Revenues of this magnitude should be sufficient to pay for routine operations and maintenance, but not for major repairs.[34] However, the range of revenue collections reported by these VWCs was very wide, with some committees saying they collected less than US$1 from all households during the entire year and others reporting household contributions greater than US$2,000. Of the VWCs in Ghana that reported charging households for water (regular or irregular payment system), nearly three quarters said that they collected enough money to pay for the cost of operations; 89 percent said that the money they collected from households would cover minor repairs, but only 41 percent said that it would cover major repairs.

Certain factors are associated with sustainability and satisfaction

Our cross-sectional research design and the nature of PCS in the three countries made it very difficult to draw definitive conclusions about the contribution of different forms of PCS to system sustainability. Nonetheless, we used multivariate models to investigate the factors (including PCS) that were associated with technical sustainability and with whether households were satisfied with the service they were receiving.

To analyze technical sustainability, we explored a variety of definitions of this dependent variable. The one we chose to report for Bolivia and Peru is simply whether or not all of the household connections were functioning in the village at the time of our visit. For Ghana, we defined technical sustainability as whether or not all the project handpumps and boreholes were operational (supplying water) at the time of our visit. Table 5.3 presents the means, medians, and standard deviations of our independent variables.

Table 5.4 reports the results of the model for each of the three countries. Some of the factors positively associated with good system performance are as expected. In Bolivia and Ghana—though not in Peru—electricity coverage is positively associated with good system performance; we think this is likely a wealth effect. In Peru, the age of the water system is negatively correlated with system performance (statistically significant at the 1 percent level), but this may be because the sample of communities in Peru included some water systems that were completed more recently than those in Bolivia or Ghana. In Bolivia and Ghana, there is no association between age and system performance; this we interpret as further evidence that the demand-driven, community management model is working as hoped in the medium term.

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[34] A 1994 study of the Afridev handpump in Ghana's Northern Region found that the average annual cost to a community of fixing common problems, such as rod breakages, plus the cost of replacing fast-wearing parts like bobbins, U-seals, O-rings, and bearings, would be about $60. UNEP's International Environmental Technology Center (1998) puts the expected operation and maintenance cost to the community at between $52 and $156 a year. VWCs in our sample reported spending about US$100 annually on repairs. None of these estimates includes the real resource costs associated with the time invested by the VDC, the caretakers, or borehole attendants.

Table 5.3: Summary statistics (mean and standard deviation) of variables used in the multivariate models

Variable name	***Variable definition***	***Bolivia (n=77)***	***Peru (n=99)***	***Ghana (n=175)***
Satisfaction	Percent of households who report being satisfied with: • maintenance and operations of piped water system (Bolivia) • maintenance and repair (Peru) • preventative maintenance and repair service (Ghana)	Mean: 83 Std. dev: 20 Median: 90	Mean: 70 Std. dev: 19 Median: 72	Mean: 0.87 Std dev: 0.15 Median: 0.92
System working	1=All sampled taps in the village are functioning (Bolivia and Peru) 1=All project handpumps in the village are functioning	Mean: 0.59 Std. dev.: 0.50 Median: 1	Mean: 0.75 Std. dev: 0.44 Median: 1	Mean: 0.90 St. dev: 0.30 Median: 1
System age	Number of years since system began operation (Bolivia and Peru) Number of years since handpumps were installed (Ghana)	Mean: 7.0 Std. dev.: 1.2 Median: 7.0	Mean: 6.7 Std. dev: 2.3 Median: 7.0	Mean: 6.0 St. dev: 0.8 Median: 6
Number of handpumps	1=village received only one handpump (Ghana)	N/A	N/A	Mean: 0.51 St. dev: 0.50 Median: 1
Population per handpump	Population per handpump installed by project (100s of persons)	N/A	N/A	Mean: 6.43 St. dev: 6.38 Median: 4.32
Electricity coverage	Percent of households interviewed with electricity	Mean: 39.0 Std. dev.: 41.2 Median: 14.5	Mean: 60.5 Std. dev: 39.5 Median: 80	Mean: 13.69 St. dev: 23.49 Median: 0
Remoteness	Distance in kilometers to… … municipality (Bolivia) ….paved road (Peru) ….area mechanic (Ghana)	Mean: 44 Std. dev.: 57 Median: 24	Mean: 58 Std. dev: 85 Median: 15	Mean: 19 St. dev: 18 Median: 15
Trust of neighbors	Percent of households interviewed who say they trust their neighbors	Mean: 83 Std. dev.: 18 Median: 88	Mean: 56 Std. dev: 18 Median: 56	Mean: 74 St. dev: 14 Median: 76
Reliable unprotected alternative source	Village has unprotected source that always has water during the dry season within 1 km of the village	N/A	N/A	Mean: 0.21 St. dev: 0.41 Median: 0
Technical training	1= During the post-construction period, water system operator or village caretaker has received technical training	Mean: 0.28 Std. dev.: 0.45 Median: 0	Mean: 0.36 Std. dev: 0.48 Median: 0	Mean: 0.39 St. dev: 0.49 Median: 0

(continued on next page)

Table 5.3: Summary statistics (mean and standard deviation) of variables used in the multivariate models (continued)

Variable name	**Variable definition**	**Bolivia (n=77)**	**Peru (n=99)**	**Ghana (n=175)**
Technical PCS visit	1= During the post-construction period… … received >1 unsolicited technically-oriented visit (Bolivia) … received >1 unsolicited visit to assist with repairs (Peru) … received >1 unsolicited free repair (Ghana)	Mean: 0.20 Std. dev.: 0.40 Median: 0	Mean: 0.07 Std. dev: 0.26 Median: 0	Mean: 0.19 Std dev: 0.36 Median: 0
Financial or managerial PCS visit	1= During the post-construction period… … received >1 unsolicited non-technically oriented visit (Bolivia) … received >1visit to assist with financial or management matters (Ghana)a	Mean: 0.10 Std. dev.: 0.30 Median: 0	Mean: 0.04 Std. dev: 0.2 Median: 0	Mean: 0.29 St. dev: 0.46 Median: 0
Regional or project identifiers	Bolivia: 1=Cochabamba Region 0=Chuquisaca Region Peru: 1 = SANBASUR program; 0 = FONCODES program Ghana: 1=Volta Region; 0 = Brong Ahafo Region	Mean: 0.50 Std. dev.: 0.50 Median: 0.50	Mean: 0.45 Std. Dev: 0.5 Median: 0	Mean: 0.48 St. dev: 0.50 Median: 0

Source: Author(s)

[a] In principle all villages in Volta should have received assistance with financial and managerial matters through the MOM program, but in practice not all VWCs perceived the MOM audits as assistance.

Table 5.4: Factors associated with technical sustainability

	Bolivia	**Peru**	**Ghana**
	HH taps functioning (1=100 percent working, 0=otherwise)	HH taps functioning (1=100 percent working, 0=otherwise)	All project boreholes in the village are working
Remoteness	β: 0.01 (S.E: 0.01) *Odds ratio: 1.01*	β: 0.00 (S.E: 0.003) *Odds ratio: 1.00*	β: 0.01 (S.E: 0.016) *Odds ratio: 1.01*
Electricity coverage	0.03[c] (0.01) *1.03*	0.013 (0.009) *1.01*	0.08[b] (0.035) *1.09*

(continued on next page)

***Table 5.4: Factors associated with technical sustainability** (continued)*

	Bolivia	**Peru**	**Ghana**
	HH taps functioning (1=100 percent working, 0=otherwise)	HH taps functioning (1=100 percent working, 0=otherwise)	All project boreholes in the village are working
Technical PCS visit	0.17 (0.83) *1.19*	1.172 (1.226) *3.23*	–1.16 (0.82) *0.31*
Financial or managerial PCS visit	0.43 (1.11) *1.54*	–1.047 (1.661) *0.35*	–0.04 (0.86) *0.96*
Technical training	1.16[a] (0.69) *3.19*	–0.390 (0.595) *0.68*	1.48[b] (0.71) *4.43*
System age	–0.42 (0.27) *0.66*	–0.346[c] (0.147) *0.71*	0.46 (0.49) *1.58*
Trust of neighbors	–0.04 (0.02) *0.96*	1.368 (2.038) *3.93*	0.04 (0.03) *1.03*
Region or program dummy variable	–2.91[b] (0.97) *0.05*	1.38[a] (0.78) *3.99*	0.77 (0.79) *2.16*
One borehole			1.99[c] (0.75) *7.31*
Population per borehole			–0.091[b] (0.037) *0.91*
Reliable alternative source			–1.98[c] (0.70) *0.14*
Intercept	7.88[b] (3.23)	1.63 (2.11)	–4.04 (4.11)
Pseudo R^2 value	*0.23*	*0.14*	*0.30*
Number of observations	*77*	*86*	*175*

Source: Author(s)

[a] Significant at .10 level.

[b] Significant at .05 level.

[c] Significant at .01 level.

In none of the three countries did we find a statistically significant association between a village receiving a technical PCS visit (to help with repairs or maintenance) and having a working water system. But post-construction technical training of system operators or caretakers was positively associated with system performance in both Ghana and Bolivia.

In Bolivia, water systems were more likely to be working in Chuquisaca than in Cochabamba. In Peru, projects in the SANBASUR program, which provided unsolicited PCS, were more likely to be working than those in the FONCODES program, which did not. In Ghana, system performance had no statistically significant association with region (Brong Ahafo, whose sample villages had no supply-driven PCS program, vs. Volta, whose sample villages had the MOM program). This finding suggests that a labor-intensive supply-driven PCS program like MOM does not increase the technical sustainability of handpump systems in a setting like rural Ghana where communities have access (on request) to many other forms of post-construction support.

The technology in Ghana (handpumps) was different than in Bolivia and Peru (gravity-fed systems with household connections), and our Ghana model has three independent variables that are not featured in the models for the other two countries: (1) whether the village had only one borehole, (2) population per borehole, and (3) whether the village had an unprotected source that could always provide water during the dry season within one km of the village. All three of these variables had statistically significant associations with system performance. If a village had only one borehole, it was more likely to be working. We interpret this to mean that the VWC makes more effort (and is under more community pressure) to keep the borehole working if there is only borehole in the village. We interpret population per borehole as a measure of the pressure on the resource and a measure of crowding. It is negatively associated with system performance—which might mean either that more intensive use of boreholes in these communities leads to a need for more difficult and expensive repairs, or that households value the handpump less when it must be shared with more households and thus put less pressure on the VWC to keep it working. Our interpretation of the negative association between having a reliable alternative source and a functioning water system is similar: households have less need for the improved water source when there is a reliable alternative source nearby; they value the improved source less, and put less pressure on the VWC to keep the handpump working (World Bank Water Demand Research Team 1993).

We used similar multivariate models to investigate what factors were associated with household satisfaction with the improved water systems. Again, we explored a variety of definitions. For Bolivia and Peru, we defined satisfaction as the percentage of households in the village who reported they were satisfied with the operation and maintenance of the water system. In Ghana, we used the percentage of households in the village who reported they were satisfied with the repairs and maintenance of the water system.[35]

Table ‎5.5 reports the results of this "satisfaction" model for each of the three countries. The striking result for Bolivia is that the share of households who are satisfied is, on average, 15 percentage points higher if the village has received a PCS visit that provided financial or managerial (though not technical) assistance. This effect is large and statistically significant, and is robust to model specification and the definition of the dependent variable. In Peru, the percentage of households that is satisfied is smaller if the water system in the village is older. This is not the case in Bolivia and Ghana.

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[35] We chose to look at satisfaction with repair, maintenance, and operations because these are within the control of the community. Satisfaction with water quality or overall satisfaction with the system may depend on construction and water-resource related factors over which communities have little control once construction has been completed.

Table 5.5: Factors associated with household satisfaction with O&M repair services

	Bolivia	Peru	Ghana
	HH satisfaction with O&M (percent satisfied)	HH satisfaction with O&M (percent satisfied)	HH satisfaction with repair and maintenance (percent satisfied)
Remoteness	β: –.01 (S.E.=.04)	β: 0.00 (S.E. = 0.00)	β: 0.00 (S.E. = 0.00)
Electricity coverage	0.18[b] (0.07)	0.00 (0.01)	0.00 (0.00)
Technical PCS visit	–3.21 (5.59)	0.07 (0.08)	–0.97[c] (0.031)
Financial or managerial PCS visit	14.64[b] (7.32)	–0.02 (0.12)	0.06[b] (0.03)
Technical training	1.94 (5.06)	0.06 (0.04)	0.06[c] (0.02)
System age	–2.17 (1.95)	–0.02[b] (0.01)	–0.001 (0.015)
Trust of neighbors	0.74[c] (0.14)	0.12 (0.14)	0.003[c] (0.001)
Region or program dummy variable	–1.58 (5.78)	0.09[a] (0.05)	0.015 (0.028)
One borehole			–0.012 (0.023)
Population per borehole			–0.004[b] (0.002)
Reliable alternative source			–0.03 (0.026)
Intercept	27.40[a] (16.35)	0.68[c] (0.12)	0.63 (0.13)
Pseudo R^2 value	*0.30*	*0.08*	0.17
Number of observations	*77*	*89*	175

Source: Author(s)

[a] Significant at .10 level.

[b] Significant at .05 level.

[c] Significant at .01 level.

In the Ghana model, the percentage of households in a village who report they are satisfied is influenced by several variables. First, consistent with the finding from Bolivia, if a village has received a PCS visit providing managerial or financial assistance, a higher percentage of households reports being satisfied. If a village has received a technical PCS visit, the percentage of households who say they are satisfied is smaller; we interpret this as evidence that the technical PCS visit was made because the equipment was already in trouble. However, technical training is positively associated with satisfaction. Villages in which a higher percentage of households report that they trust their neighbors also have a higher percentage of satisfied households. Finally, in Ghanaian villages with large populations per borehole, a smaller percentage of households are satisfied; we interpret this as consistent with the results for population per borehole in Table ↱5.4 above.

5.2 Lessons learned

If these findings turn out to be as robust as we hope, it seems that demand-driven, community management, coupled with access to spare parts and some technical expertise, is succeeding as an approach to rural water supply provision in developing countries. Important puzzles remain, however, for policy makers, investors, and managers in rural water supply systems. These are discussed below, and the chapter then concludes with suggestions on themes for further research.

Implications for maintaining and expanding rural water supply systems

Our conclusions on the relationship between post-construction support and sustainability are more tentative than those on the workability of the demand-driven, community management model, and merit further investigation in other field sites. The communities in our study solicit and use a wide range of post-construction support services. We find no evidence that providing communities with free repairs or free technical assistance, or implementing an intensive supply-driven post-construction support program like MOM in parts of Ghana, improves technical sustainability or increases household satisfaction.

This supports the wisdom of the original conception of the demand-driven community management model—that communities can and should take full responsibility for their systems. The unsolicited PCS activities that appear most promising from this study are those that help communities to renew and further develop their capacities: post-construction training for system operators and non-technical support visits to help VWCs with administrative functions or water use disputes.

Our findings also present some major puzzles for proponents of the demand-driven, community management model.

The first puzzle is that even communities whose cost-recovery systems seem to be meeting program objectives (i.e., those villages that pay 5–10 percent of capital costs and collect tariffs to cover operation, maintenance, and repairs) are not moving toward a financially sustainable future in which they can either (1) replace infrastructure when it reaches the end of its economic life, or (2) expand system capacity to accommodate population and economic growth. The donor-funded rural water supply programs studied have been structured as one-time investment programs, designed to meet only the immediate needs of rural communities. This means that the moral obligation assumed by higher-level government and donors is not over. The current financing system ensures that these communities will keep returning for capital subsidies, just as some are doing now for repairs.

In large municipalities, new water systems are routinely designed with excess capacity in both the distribution system and the water source to provide for growing populations. But in the rural water sector everywhere, capital subsidies are limited, and excess system capacity is one of the first casualties when investment funds are scarce. Moreover, few demand-driven rural water supply programs have incorporated a systematic approach for providing follow-up capital subsidies to villages that have outgrown their current systems or want to upgrade to a higher-level of service. Though some observers might argue that this is not a problem—that as long as poor people need help they should get it—the indirect consequences of this capital-financing model need to be carefully considered.

In Bolivia, one consequence of a per capita cap on capital expenditure (designed to provide a disincentive for communities to ask for capital-intensive, perhaps inappropriate, facilities) seems to have been that some communities restricted their service boundaries, leaving households on the periphery without piped services. These unconnected households were provided with wells, but they may prefer in future to upgrade to the level of service enjoyed by their neighbors. Expanding coverage in these Bolivian systems will be complicated by the fact that the water sources in many villages are not large enough to serve more people; already two thirds of the women who participated in our focus group discussions felt that the quantity of water provided by PROSABAR systems was insufficient or "just enough to meet community needs." About 20 percent of the PROSABAR communities studied had experienced decreases in the quantity of water supplied during the dry season in the period since their system was constructed.

In Ghana, part of the reason why some households continue to rely on traditional water sources appears to be that capital subsidies were spread too thinly, and that too few boreholes were installed to serve a growing population. Some of the communities in Ghana need to plan for piped distribution systems that can support new businesses and other enterprises, and the current model for the provision of subsidized boreholes will not ease this transition. Without the option of gravity-fed distribution systems such as in Peru and Bolivia, the Ghanaian communities will have higher O&M expenses. They will also need to plan for expenditures on system expansion. For a village to do this on its own will require a cost-recovery system that can generate a much larger and more regular stream of revenue.

This brings us to the second puzzle: why is it that the VWCs in a significant number of villages are not collecting tariffs at all, or are collecting too little revenue from households to cover the financial costs of major repairs—much less the costs of system expansion or capital replacement? One possible explanation is that villagers' required initial contribution to capital costs (5–10 percent of capital cost through cash or in-kind contributions) was too small to act as an adequate demand filter—that is, to exclude households who could not afford the full financial (and non-pecuniary) costs of operating and repairing the new systems. We cannot rule out a possible link between low capital contributions and poorly performing tariff collection systems. But neither do we have evidence that increasing the initial capital contribution would lead to better cost-recovery from households.

Rather, our findings suggest three other reasons why VWCs are unable or unwilling to charge households more. First, generating substantial cash balances creates problems for the VWCs. These rural communities lack access to a convenient, secure banking system for the management of cash. Among the villages in our sample, those in Bolivia were a median distance of 24 km to the nearest municipality, those in Peru were on average 15 km from a paved road, and those in Ghana were on average 15 km from the urban centers where the area mechanics live and work. Moreover, many households have little cash to spare, and cash flow is irregular and highly seasonal. Households are also often distrustful of the accounting and security of cash balances, and VWC members may distrust each other or not want the responsibility of securing cash.

Second, when VWCs do accumulate cash balances, villages often want to spend these monies on other development projects. There is thus little incentive for VWCs to attempt to generate the funds necessary for major repairs to the water system if they will "lose" them anyway. In such a situation, it makes sense to just try to raise funds when the need arises. For all these reasons, life is much simpler for members of VWCs if the cash on hand is only sufficient to pay for minor O&M costs or is only collected at the moment when funds are needed.

Third, VWCs may well be right to believe that future capital and repair subsidies will be forthcoming when needed, whether from donors, NGOs, or higher levels of government. In the projects studied, not only was the bulk of the capital provided at no cost to the communities at the time of construction, but a significant number of VWCs in our sample had found ways to insulate households from the cost of repairs to the water systems. They had obtained donations, free spare parts, and free repairs from a wide variety of NGOs, church organizations, private individuals and companies, and even local governments.

Herein lies a third puzzle for rural water supply policy: does the sector's current capital financing model—and the post-construction activities of these NGOs and other actors—create a moral hazard that will undermine the principle of community self-reliance in the post-construction phase?

In Ghana, the fact that one in six of the sample villages had received grants from outside sources after the construction of the project may not seem very significant, but it does suggest that almost all VWCs would know that NGOs and others are active and nearby. For a committee, it may seem like a reasonable bet to wait until major repairs are needed and see if an NGO might provide the cash required. Moreover, an effort by a VWC to establish some kind of sinking fund to make major repairs and replace capital at some future date may make the community appear less needy to an NGO, and preclude it from receiving such support. Indeed, small towns in the United States face similar disincentives to financing their own capacity expansion and system rehabilitation.

To an NGO, repairing a handpump or fixing a broken transmission line for a piped distribution system may well seem like an ideal project, offering its funds great perceived leverage. With a relatively small amount of incremental funds, the NGO can reasonably claim to its donor base that all benefits of the infrastructure are due to its involvement, because without the incremental investment the system would have remained broken. NGOs (and indeed other donors) are especially attracted to such opportunities.

This approach to development assistance raises two important questions. First, would the community have managed to raise funds locally and made the repair if the NGO had not been ready to step in? Second, if all the kudos for the infrastructure goes to the last investor that contributes, who will be willing to continue making the capital infusions necessary to replace the aging capital stock, i.e., to do the "heavy lifting" that is required under this capital financing model? Will higher levels of government and donors step into these rural communities five or ten years down the road, when these systems are fully depreciated, and replace the capital that NGOs have kept running?

The situation in the rural communities in our sample is not financially sustainable without new infusions of capital relatively soon—both to replace existing infrastructure and to provide for economic growth. The moral hazard from the active involvement of NGOs, religious groups, and other non-state actors in the rural water sector is likely to prove an important factor undermining cost-recovery efforts and may discourage communities from making their own investments in water infrastructure to support economic growth.

Achieving long-term financial sustainability requires a different policy model. Communities do want and need help, but this assistance should not perpetuate their dependency on NGOs or on higher levels of government for limited capital subsidies that lock them into infrastructure systems that are unsuitable for achieving economic development or for accommodating growing populations. Nor should it undermine local initiatives to pay for higher levels of infrastructure or infrastructure expansion. Methods for achieving better coordination of the policies of NGOs with government and with each other seem especially important and worthy of future research. NGOs' involvement in the sector has proven important for fostering policy innovation, serving the poorest of the poor, and helping communities to find the resources they need to keep their water systems running. But, as suggested by our findings, NGOs can also create moral hazard problems that may ultimately undermine rural economic development. One important role for NGOs in future could be as catalysts for post-construction support, rather than as dispensers of capital subsidies for communities that cannot manage to repair their water projects.

In summary, the demand-driven, community management planning model has come a long way towards finding the key to success in the rural water sector. The next frontier seems to be the design of a policy framework that will enable communities to handle the twin challenges of system rehabilitation and expansion.

5.3 Suggestions for further research

Many unexplored questions lie ahead for additional research. Our research design, given its ex-post, cross-sectional nature, did not allow us to compare benefit measures before and after the projects were constructed, or provide an opportunity to understand how PCS has changed and affected sustainability over time. Donors should consider more systematically monitoring PCS programs in which they have invested resources, to gather additional data for analysis. Fieldwork considerations also deserve mention. Though our project enabled us to estimate the impact of PCS over much larger samples than in previous studies, our village sample sizes were still quite small. Future studies that investigate PCS over a wider cross-section of villages would yield more precise and robust findings, while case-study research within specific villages would help to understand the dynamics of PCS and how or why PCS has been effective in some areas while failing in others.

The large number of communities with functioning systems and satisfied users provides evidence that the water sector is learning from its mistakes and that community-based models of development can effectively bring potable water to people over time. It would be interesting to learn whether different types of PCS can "make or break" the maintenance and use of a water system in a more challenging setting, or whether other project and community factors are preconditions for PCS to work effectively.

As water practitioners urge villages to begin setting aside their own funds to replace and expand their systems, more research will be necessary to determine whether a systematic PCS effort can help enhance the capital side of financial sustainability (and what resource costs are necessary to achieve this). Household-level models that predict the effects of PCS on individual payments would strengthen the existing literature on economic demand. In particular, studies that specify measures of the economic benefits of village water supply projects can help in comparing the costs and benefits of providing PCS programs.

Finally, in-depth longitudinal studies that collect data on economic benefits in communities that received varying forms of PCS could help to pinpoint when communities asked for assistance of various types, and when they received it, and assess how the assistance affected the consistency of system performance and benefits. Such studies would isolate how effectively post-construction assistance responds to specific problems, and would compare communities that demand and obtain more external support with communities that try to rely on their own resources until their systems need a complete overhaul. Research on all of these topics would assist policymakers in designing PCS programs that better enable communities to be efficient stewards of their drinking water resources.

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